RUTGERS
Edward J. Bloustein School
of Planning and Public Policy

RUTGERS
Center for
GREENBUILDING

COSTS AND BENEFITS OF RESIDENTIAL ENERGY EFFICIENCY INVESTMENTS

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1 Executive Summary

This study investigates the costs and benefits of investments in residential energy efficiency in New Jersey. It uses an engineering-economic modeling approach to assess the construction costs, operational savings, and net life-cycle costs of a variety of energy-efficiency options that may add value to a typical new home constructed in New Jersey. Each energy-efficient option is compared to a baseline, single-family detached home with a floor area of 2180 square feet that is typical of the New Jersey residential real estate market. The baseline building meets the updated New Jersey energy code based on IECC 2009 that enters effect in March 2011.

The assessed alternatives include improvements to passive features of the building envelope, active elements of the home's mechanical systems, solar energy generation, and multi-technology bundles designed to earn an ENERGYSTAR rating or LEED certification. Low, medium, and high upgrade levels are modeled within each category of alternative improvements. All candidate improvements are commercially available in New Jersey.

The following table summarizes the results of this study. It shows that although the new energy code is much more stringent than its predecessor, there remain a variety of options for achieving further improvements on the order of 20% – 30% in residential energy efficiency. These options are financially attractive even on a pre-tax basis. Much deeper savings are also technically feasible but few of those alternatives are currently cost-effective.

A variety of envelope and equipment improvements are cost-effective and likely to hold their value upon resale, especially when assembled into synergistic packages that allow downsizing of equipment. Solar systems remain attractive for well-capitalized homeowners, although their cost-effectiveness is highly dependent on future SREC values. Energy Star labels and LEED certifications do not intrinsically connote cost-effectiveness, but a good designer can work within those frameworks to achieve superior performance by bundling together energy-efficient features.

Alternative	**% Energy Savings from Baseline**	**Simple Payback in Years**	**Alternative**	**% Energy Savings from Baseline**	**Simple Payback in Years**
Envelope Upgrades			*Solar Upgrades*		
Basic Framing/Insulation	14	0	Basic Solar	6	7
Enhanced Framing/Insulation	27	0	Enhanced Solar	11	7
Door/Window	6	14	Advanced Solar	22	7
Enhanced Framing/ Insulation with Door/ Window Upgrade	30	4			
Active Mechanical Upgrades			*ENERGY STAR / LEED Upgrades*		
Low Level Mechanical	14	9	ENERGY STAR Basic	13	25
Mid-level Mechanical	18	15	ENERGY STAR Enhanced	30	8
High Level Mechanical	45	32	ENERGY STAR Advanced	62	62

2 Introduction

The goal of this study is to understand the costs and benefits of investments in residential energy efficiency in New Jersey. The study achieves this goal for a range of energy efficiency options by estimating the construction cost for each option, modeling associated energy savings and changes in a building's operating costs, and netting out those two costs within a life-cycle costing framework. These techniques allow for the quantification and comparison of the initial costs (e.g. purchase, installation) and lifetime operating savings. The effects of energy efficiency investments on the dollar value of homes also receives attention. In particular, we turn to *The National Green Building Investment Underwriting Standards for Residential Buildings* to help evaluate the effects of energy efficiency investments on home value, as well as offer suggestions to extend the usability of the standard.

Investments in green building and energy efficiency as a component of green building have continued to increase over the past several years despite the economic downturn. This is evidenced not only by the increasing number of green buildings, but also in the continued increase in the number of professionals trained in green design, and of cities that have adopted green building programs, guidelines or requirements.

2.1 Residential Green Building at the National Level

At the national level, the Department of Energy (DOE)/Environmental Protection Agency's (EPA) ENERGY STAR® Program is the most popular and widely implemented program with one million ENERGY STAR® labeled homes having been built in the United States since the program began in 1995.[1] The National Association of Home Builders (NAHB) Program follows with over 135,000 green homes that have been built and certified by NAHB members participating in voluntary local green building programs that utilize the NAHB Model Green Home Building Guidelines since 2005.[2] The U.S. Green Building Council's (USGBC) LEED for Homes Program is currently a small but influential program in the residential market with over 2,500 certified homes since its launch in 2008. In addition, new residential green building programs continue to be developed, including the

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[1] U.S. Environmental Protection Agency (USEPA). 2010. Celebrating 1 Million ENERGY STAR Homes. http://www.ENERGY STAR.gov/index.cfm?fuseaction=mil_homes.showSplash (accessed March 12, 2010)

[2] Emily English (2008) NAHB National Green Building Program. (Presentation May 29, 2008). Available at: http://epa.gov/air/caaac/pdfs/2008_05English.pdf

U.S. Department of Energy's (DOE) Builders Challenge and the ANSI approved ICC-700-2008 National Green Building Standard.

2.2 Residential Green Building in New Jersey

New Jersey is a leader in green home building. There are more than 47,000 ENERGY STAR Qualified homes built to date in New Jersey and 47 LEED certified homes program.[3][4] In addition, affordable green housing in New Jersey is incentivized through the NJ Home Mortgage and Finance Agency's (NJMHFA) Green Future Guidelines.[5] The incentives for green home building that are made available to buildings in New Jersey are not incidental to its leadership position and are consistent with the state's mission to promote energy efficiency and reduce greenhouse gas emissions. The residential sector accounts for 22.6%[6] of energy use and 36.8%[7] of electricity consumption in the state, and therefore accounts for about 1/3 of its greenhouse gas emissions.

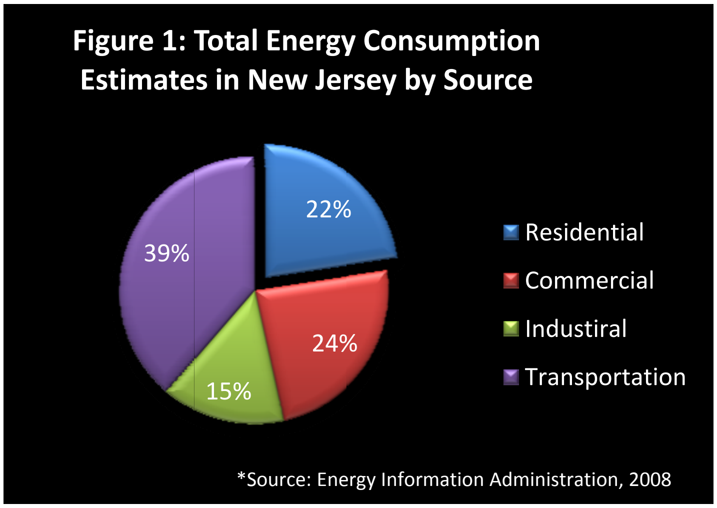
Figure 1: Total Energy Consumption Estimates in New Jersey by Source

*Source: Energy Information Administration, 2008

The New Jersey Office of Clean Energy (OCE) administers New Jersey's Clean Energy Program, which promotes increased energy efficiency through financial incentives and informational programs for residential, commercial, and municipal customers.[8] In 2009, the OCE designated three incentivized tiers of residential building efficiency. Tiers 1 and 2 reflect ENERGY STAR construction with maximum Home Energy Rating System (HERS) Indexes of 85 and 65,

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[3] U.S. Environmental Protection Agency. 2010. New Homes Partners in New Jersey (accessed 11/22/2010) http://www.ENERGY STAR.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=NJ
[4] U.S. Green Building Council. 2009. LEED for Homes Certified Projects by State (accessed 12/22/2009) http://www.usgbc.org/ShowFile.aspx?DocumentID=2683
[5] The Green Future Guidelines are referenced by and developed for the Low-Income Housing Tax Credit Green Point, Single Family CHOICE Program, the Balanced Housing and Home Express Green Requirements, and the Special Needs Housing Trust Fund Sustainability Guidelines to address green building requirements or recommendations.
[6] Energy Information Administration. State Energy Data System 2008: New Jersey, available at http://www.eia.doe.gov/emeu/states/sep_sum/html/pdf/sum_btu_1.pdf
[7] NJ Energy Data Center. Energy Information Administration. State Energy Profiles
[8] New Jersey's Clean Energy Program http://www.njcleanenergy.com/

respectively; Tier 3 is reserved for the New Jersey Climate Choice Home, which must achieve a maximum HERS Index of 50 before the addition of renewable energy technologies (which are required by the program).[9] A HERS Score of 100 represents average home energy consumption based on IECC 2006, while a score of 0 would represent a net zero home.

Performance data relating to the OCE programs and related items are collected on a regular basis. As a result, we know that:

- 5,509 ENERGY STAR Homes were built in NJ in 2006 and 6,180 ENERGY STAR Homes were built in 2007. The 6,180 ENERGY STAR Homes represented about 27% of the 23,140 Certificates of Occupancy issued in 2007.[10]

- 4,838 ENERGY STAR homes were built in NJ in 2010. There are 49, 198 ENERGY STAR qualified homes built to date in the state. [11]

- The average size of a NJ ENERGY STAR New Home is 2,500 sq ft, with an average incremental cost of $2,500.[12] EPA cost analysis for ENERGY STAR Qualified Homes 2011 guidelines suggest an approximate incremental cost range from $4,000 to $5,000, which still results in an incremental monthly mortgage which is lower than the expected monthly savings of the ENERGY STAR home; thus, NJ appears to remain ahead of the cost curve.[13] However, when comparing ENERGY STAR homes to typical new homes in New Jersey, the difference in performance and cost—and thus, relative savings—is shrinking because conventional new homes have improved as the marketplace has transformed.[14]

- New homes that have pursued substantially greater energy efficiency than the ENERGY STAR minimum are in fact reaping substantial benefits. In NJ, each HERS point appears to

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9 The NJ Climate Choice Homes is based on the EPA Climate Choice Home. See, Advanced New Home Construction http://www.epa.gov/cppd/climatechoice/

10 KEMA Associates. 2009. New Jersey's Clean Energy Program: Residential New Construction Program Impact Evaluation. Prepared for the New Jersey Board of Public Utilities. p. 2-1.

[11] ENERGY STAR FACTS http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=NJ

12 Center for Energy Environmental and Economic Policy, Rutgers University. 2010.

13 U.S. EPA ENERGY STAR. 2010. ENERGY STAR 2011 Fact Sheet. http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/2011_Fact_Sheet.pdf

14 KEMA Associates. 2009. op. cit. p. 1-5.

be associated with a 2.8% reduction in the energy usage per square foot. This greater average reduction in energy use may be associated with quality control measures such as the Thermal Bypass Checklist, which is not required by the current version of the ENERGY STAR program but is required in NJ.[15]

- A $10 per month difference in utility bills is worth the same as a $1,500 change in the sale price, assuming a seven percent mortgage interest rate over 30 years.[16] Considering that (a) the average annual residential energy bill in the Mid-Atlantic states in 2007 was $2,279;[17] and (b) the average annual savings in energy for new ENERGY STAR homes compared to new conventional homes in New Jersey is about 10%;[18] then (c) on a life-cycle cost basis there is room for traditional homeowners to invest several thousand dollars more in energy saving features.

In addition, studies designed to detect whether ENERGY STAR and other green labels increase a property's value at the time of sale are finding a significant and positive effect. These studies control statistically for the effects of location, size, and amenities, and thereby estimate the extent to which the bundle of green features delivers value that can be capitalized into a sales price.[19] In recent studies of commercial buildings, the premium in market value ranges from 5% to 20%, with the most recent study reporting 8.5% for ENERGY STAR properties.[20] Older studies of residential buildings confirm that energy efficiency is also capitalized into housing prices in the United States and elsewhere, but more recent studies focusing on ENERGY STAR program impacts are not yet

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[15] KEMA Associates. 2009. *op. cit.* pp. 1-5, 5-1, 5-2.

[16] California Energy Commission. 2009.Raise Your Energy Efficiency I.Q. http://www.energy.ca.gov/2007publications/CEC-400-2007-001/CEC-400-2007-001-BR.PDF

[17] U.S. Dept. of Energy, Energy Information Administration. 2009. *Residential Energy Consumption Survey 2007*. Table US10. Retrieved March 14, 2010 from http://www.eia.doe.gov/emeu/recs/recs2005/c&e/summary/pdf/tableus10.pdf.

[18] KEMA Associates. 2009. *op. cit.*. pp. 1-5, 1-6.

[19] The theory underpinning this approach is explained in Sherwin Rosen. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition, *The Journal of Political Economy*, Vol. 82, No. 1. (Jan. - Feb., 1974), pp. 34-55.

[20] Gary Pivo and Jeffrey D. Fisher. 2009. Income, Value and Returns in Socially Responsible Office Properties. Working paper. Retrieved on March 14, 2010 from http://www.responsibleproperty.net/pa/ge/research. See also: Eichholtz P, Kok, N and Quigley JM (2009), Doing Well by Doing Good? An analysis of the financial performance of green office buildings in the USA. RICS, London, March 2009. Fuerst F and McAllister P (2008), Pricing Sustainability: An empirical investigation of the value impacts of green building certification. Paper presented at the American Real Estate Society Conference, April, 2008. Miller N, Spivey J, and Florance A (2008), Does Green Pay Off? *Journal of Real Estate Portfolio Management* 14(4): 385-400. Wiley JA, Benefield JD and Johnson KH (2008), Green Design and the Market for Commercial Office Space. *Journal of Real Estate Finance and Economics*, 10.1007/s11146-008-9142-2.

available in the peer reviewed literature.[21] In any case, the hedonic approach is not suitable for weighing both the benefits AND costs of energy efficiency investments because it only considers the benefits part of the equation.

3 Research Methodology

This project evaluates the costs and benefits of residential energy efficiency investments within an engineering-economic analysis framework. The work includes five major stages of analysis in which we: (1) specify a baseline or conventional building and a range of associated energy-efficiency scenarios; (2) develop a construction cost estimate for each scenario; (3) estimate energy-related operating costs for each scenario using a simulation model; (4) calculate life-cycle costs and associated financial metrics for each scenario; and (5) link these costs to real estate values. The following paragraphs introduce the modeling framework and the scenarios.

3.1 Energy Modeling

Energy modeling is a key component of the analysis of energy efficiency alternatives being conducted by the Rutgers Center for Green Building. Modeling the energy use of a home is a complicated process that involves creating a digital representation of the building including details on the construction of the building, the location and climate, internal heating and cooling set points, heating and cooling equipment, and schedules of use for lighting, appliances and other energy uses. The first model created is the baseline home, which represents the building as it is initially designed. After this model has been created, specific variables are altered to create alternate scenarios. Energy models are particularly effective for estimating the differences in energy use between these scenarios. These scenarios allow us to consider the effects of different materials, equipment and/or building designs, identifying the most effective energy efficiency investments.

There are a variety of software packages available to create and analyze energy models. REM/Design™, the energy modeling software being used for this analysis, is specifically designed

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[21] Ruth C. Johnson & David L. Kaserman. 1983. Housing market capitalization of energy-saving durable good investments. *Economic Inquiry* 21(3): 374-386. Dinan TM and Miranowski JA (1989), Estimating the Implicit Price of Energy Efficiency Improvements in a Residential Housing Market: A Hedonic Approach. *Journal of Urban Economics* 25: 52-67. Silvia Banfi , Mehdi Farsi, Massimo Filippini, Martin Jakob. 2003. Willingness to Pay for Energy-Saving Measures in Residential Buildings. Working paper. Retrieved on March 14, 2010 from http://doc.rero.ch/lm.php?url=1000,43,6,20070327092800-ZZ/filippini_EE_2007_2.pdf.

for residential buildings and is a more detailed version of the REM/Rate software, which is used by Home Energy Rating System (HERS) raters throughout the country. REM/Design™ calculates heating, cooling, hot water, lights and appliance loads based on the climate, orientation, and design of the home. This modeling software analyzes the performance of numerous energy design features including envelope insulation, air leakage control, duct leakage control, active and passive solar systems, heating and cooling equipment, and mechanical ventilation. In addition REM/Design™ enables the proper sizing of heating and cooling equipment and helps determine compliance with ASHRAE 90.2 and the International Energy Conservation Code (IECC). REM/Design™ is also DOE-approved for energy savings calculations for the Weatherization Assistance Program.

Energy modeling results include annual consumption by system. This level of detail facilitates an understanding of the potential tradeoffs that occur when making particular energy investments. For example, sealing a home very tightly can significantly reduce energy use by reducing air leakage, but it also makes it necessary to use a mechanical system to bring fresh air into the home, which requires additional energy to run. Thus, the detailed results of an energy analysis enable a more complete understanding of the energy tradeoffs inherent in each modeling decision. In addition the energy model can be used to calculate a HERS Index score for each alternative. The **HERS Index** is a scoring system in which a home built to the specifications of the HERS Reference Home (currently based on the 2006 International Energy Conservation Code) scores a HERS Index of 100, while a net zero energy home scores a HERS Index of 0. The lower a home's HERS Index, the more energy efficient it is in comparison to the HERS Reference Home. Each 1-point decrease in the HERS Index corresponds to a 1% reduction in energy consumption compared to the HERS Reference Home.[22]

3.2 Baseline Home Model

The core of our analysis consists of comparisons between the baseline model and alternate cases designed to test specific energy efficiency investments. The baseline model is a single family detached home which represents standard construction practices for new homes and serves as the

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[22] U.S. EPA. 2010. What is a HERs Rating? http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS

basis of comparison for all of the alternate scenarios. [23] In terms of energy, the standard construction techniques are based on the requirements of the International Energy Conservation Code (IECC) *for 2009*. Although, IECC 2006 is the current code in New Jersey, IECC 2009 has been adopted and will be fully in effect in March 2011. By updating our baseline model to IECC 2009, we are ensuring that our results are not out of date shortly after the report is completed. The requirements of IECC 2009 vary by climate zone of the location. New Jersey is split between zones 4 and 5 with Middlesex County being located in Zone 4 (see Figure 1). Buildings in Zone 4 are required to have walls insulated with at least R-19, ceilings with at least R-38, and floors with at least R-30. IECC 2009 also requires that windows and doors to have a U-factor of 0.35.

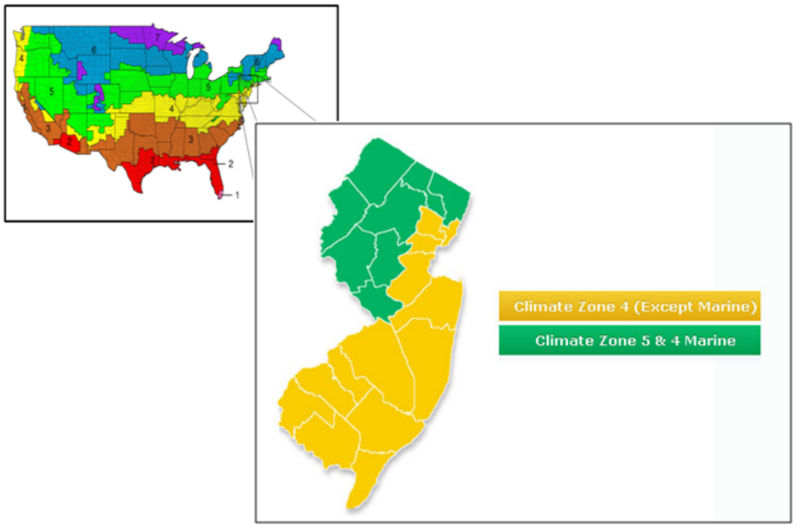

Figure 2. New Jersey Climate Zones

The single-family detached baseline home is modeled as a two-story home of 2,180 square feet, roughly square in shape. It has 60 s.f. of glazing on the north and east sides of the home and 72 s.f. of glazing on the south and west sides of the home. It is heated by a natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) of 78%, cooled by an air conditioner with a Seasonal Energy Efficiency Rating (SEER) of 13, and provided with hot water by a natural gas fired water heater with an Energy Factor (EF) of .57. These choices represent the typical or minimum allowed levels for new homes in New Jersey. As it is currently modeled, a homeowner for this home would

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[23] We considered using a typical single-family townhouse as a second baseline, but because the building specifications were so similar to the single family detached home it was decided that no new or relevant information would come from using both models.

spend $1,470 for natural gas and $1,496 for electricity annually. The specific energy consumption by system is listed in Table 1, below.

Table 1. Energy Use in the Single Family Detached Baseline Home

Energy Use	**Amount**
Heating (MMBtu)	75.5
Cooling (MMBtu)	3.7
Water Heating (MMBtu)	20.0
Lights & Appliances (MMBtu)	23.4

A sample image of the baseline home is provided below in Figure 3. This home is not exactly what was modeled, but provides a reasonable approximation of the modeled home.

Figure 3. Baseline Home (Single Family Detached Home Sample Image)

Source: Sanib Lemar, via Wikimedia Commons

3.3 Scenarios and Analyses

Having modeled the baseline scenario, we then compare it to the following alternate scenarios which are discussed in detail in a section below.

- Passive energy-efficiency strategies that focus on improving the building envelope
- Active energy-efficiency strategies that focus on improving the heating, ventilating and air conditioning systems

- Solar strategies that place photovoltaic cells on the roof to generate electricity
- ENERGY STAR-rated house designs
- LEED-certified house designs

The scenarios have been constructed at two levels. First, we model more efficient single technologies, such as increasing levels of insulation. This aids in identifying cost-effective best practices but misses the potential conflicts and synergies that arise when integrating building systems together. Therefore, we next combine bundles of technological choices into integrated packages in order to compare the relative cost-effectiveness of designs targeting standard designations such as ENERGY STAR and LEED at the Silver, Gold, and Platinum levels.

3.4 Life Cycle Costing (LCC) – Cost Effectiveness Analyses

Elements such as superior insulation, highly efficient HVAC systems, and photovoltaic arrays cost more to install than traditional elements, but they also have a significant impact on the lifetime cost of operating the home. These long-term benefits make it essential to examine these systems in terms of their overall cost rather than simply their initial cost. **Life-cycle cost** (LCC) refers to the total cost of ownership over the life of an asset. The life cycle costing (LCC) of the models includes the initial cost of each alternative as well as the value of energy savings and, in the case of solar improvements, revenues, via solar renewable energy credits (SRECs). Initial costs (purchase prices) for each of the energy features, or feature bundles, are estimated using a variety of tools, including RSMeans CostWorks Online[24][25], local manufacturers' representatives, and data collected in previous green home studies. Forecasting for external variables, including energy prices, discount rates and inflation rates is another key element of the analysis. Sources of this information include the U.S. Department of Energy (DOE) Annual Energy Outlook[26] and forecasts from the Rutgers Economic Advisory Service.[27] The annual escalation rate for energy prices extrapolates from the most recent 20 years of data for New Jersey (1.3%). In sensitivity analysis, this project also examines a high-price case based on extrapolation of the most recent decade of New Jersey data (3%), and a low-price case based on no change from current levels (0%). An annual discount rate of 5% is applied in the net

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[24] SRECs are purchased by utility companies to meet the requirements of NJ Renewable Portfolio Standard and often by other companies to demonstrate their commitment to sustainability. In recent years, the value of SRECs has been high and increasing, and a main factor along with federal tax deductions that investments in solar energy have paid off.

[25] RS Means Cost Works. 2010. http://www.meanscostworks.com/

[26] US DOE Buildings Energy Datebook http://www.eia.doe.gov/oiaf/aeo/

[27] RECON- Rutgers Economic Advisory Service. 2010. http://policy.rutgers.edu/cupr/recon/

present value calculations discussed below. This approximates a typical homebuyer's current cost of capital in the retail mortgage market.

An important component of LCC practice is the estimation of **Net Present Value** (NPV). NPV analysis takes into account both the initial cost of each system and the energy savings that will accrue over the life of the home, helping to clarify the costs associated with making certain decisions.[28] For example, choosing to invest in a more expensive and efficient HVAC system removes the ability to invest the same money in some other way, so the potential return from these alternatives is forgone. NPV analysis aids in understanding the relationship between money spent in the present and returns that will be received in the future. Simple payback analysis is another useful financial metric through which to view investments in energy efficiency. **Simple payback** considers the initial investment costs and the resulting annual cash flow to determine the amount of time it takes for an investment to pay for itself. [29] NPV and simple payback are complimentary calculations that can be used by an investor to determine if project is economically viable. Both metrics are used in this analysis.

Projections of the future are, by their nature, uncertain. As a part of our analysis we conduct a series of sensitivity analyses to understand the effects of uncertainty on the costs and benefits of the scenarios.

3.5 Valuation

ENERGY STAR and more recently LEED labeled homes have come to represent green home building in the U.S. The National Green Building Investment Underwriting Standards: Residential Buildings (herein: Underwriting Standard) was created by the Capital Markets Partnership to address an increasing interest in assigning dollar value to homes attaining LEED, ENERGY STAR, Climate Neutral, and Green Point[30] certifications.[31] To accomplish this goal, the Underwriting Standard uses

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[28] NPV is the sum of the net cash flow at a certain time divided by the sum of 1 plus the discount rate raised to the time of the cash flow.

[29] If annual cash flows are equal, the payback period is found by dividing the initial investment by the annual operating savings. The payback period is usually measured in years.

[30] The GreenPoint Rating is a green building certification program based out of California. GreenPoint evaluates a home based on its performance in five categories: indoor air quality/health, energy, community, resource conservation and water conservation. There are over 300 possible points available in this rating system. CMP has approved GreenPoint as an equivalent to the LEED rating system in terms of residential asset underwriting. Other rating systems may also be

relevant LEED and/or GreenPoint Rated points, a building's ENERGY STAR score, and Climate Neutral status to derive a CMP (Capital Markets Partnership) Green Value Score, which range from 0-100.[32] The Green Value Score is intended to complement existing underwriting methodologies and does not replacement them. If the Underwriting Standard were to gain market acceptance, green buildings might be viewed favorably in terms of their loan-to-value ratios, interest rate discounts, fee waivers or reductions and other benefits as could be bestowed by the financial lending institutions.

Eighty-five percent (85%) of the Green Value Score focuses on energy and water efficiency, location, and indoor environmental quality. Subsets of energy, water, etc., attributes are drawn from a generic LEED for Homes scorecard such that the user of the Green Value Score can refer to the scorecard for a LEED project or can apply these same categories to score a non LEED project evidencing these attributes. Each of the attributes included by CMP in the scoring sheet are believed by the organization to have a positive tangible impact on an asset's operating profile and/or ability to generate ongoing revenues.[33] These various green building attributes are next assigned a score based on a combination of the appraiser's view of the property and a built-in adjustment factor (assigned by CMP). The scoring done by the appraiser is bounded by a point range, which is 0 at its lowest and 5 at its highest, depending on the particular green building attribute being scored. Finally, an accredited environmental professional (including LEED AP), licensed architect or licensed engineer must validate the CMP Green Value Score. Validation of the CMP Green Value Score is required due to the fact that: 1) an ENERGY STAR score below 75 is not certified by the EPA ENERGY STAR program. Scores below 75 are self-administered and must be independently verified; 2) a LEED certified building (any certification level) requires a judgment as to value range associated with the attainment of the various LEED points contained in the scoring mechanism; and 3) a non-LEED certified building can be awarded points under this Underwriting Standard. The Figures below, reprinted with permission of the Capital Markets Partnership, provide an illustration of the scoring methodology described above.

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equivalent to any of the standards used within the National Green Building Investment Underwriting Standard, but they must be approved by CMP.

[31] The National Green Building Investment Underwriting Standards: Residential Building, unanimously approved September 2, 2008, pp. 3-5, Capital Markets Partnership.

[32] The Capital Markets Partnership is a collaboration of financial institutions, investment banks, real estate investors, governmental entities, NGO's, non-profits, and other interested parties. A full list of Partnership members is available in Section 17.0 of the Standards, op cit.

[33] The National Green Building Investment Underwriting Standards: Residential Building, unanimously approved September 2, 2008, pp. 17, Capital Markets Partnership.

Figure 4: The CMP Green Value Score Matrix (from page 16) [34]

CMP GREEN VALUE SCORE MATRIX	**Score**	**Value Ratio**	**Adjusted Score**
ENERGY STAR Yardstick Score / Converted HERS Rating		40%	
Green Building Underwriting Standard Score		35%	
LEED / GreenPoint Rating	**NONE**	0%	
	CERTIFIED or 50-94 GPR points	2%	
	SILVER or 95-149 GPR points	5%	
	GOLD or 150-209 GPR points	10%	
	PLATINUM or 210+ GPR points	15%	
Climate Neutral Certified	YES	10%	
	NO	0%	
CMP GREEN VALUE SCORE		**100%**	

HERS / ENERGY STAR CONVERSION TABLE

HERS Rating	**Score**
100	50
90	55
80	60
70	70
60	80
50	90
40	95
39 and below	100

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[34] The charts illustrated below are reprinted with the permission of the Capital Markets Partnership.

Figure 5: Green Building Underwriting Standard Score Calculation Methodology (pg. 22)

Calculation Methodology - Green Building Underwriting Standard

Sorted by LEED criteria / building attribute	LEED Point		Value Range		SCORE	Adjustment Factor	TOTAL
	YES	NO	Low	High			
Site Selection	x		0	1	1	1	1
Preferred Location & Infrastructure	x		1	3	3	3	9
Community Resources & Public Transportation	x		0	4	4	3	12
Heat Island Effect	x		0	1	1	1	1
Water Efficiency / Use Reduction	x		0	1	1	3	3
Energy Efficiency	x		1	5	5	3	15
On-Site Renewable Energy	x		1	3	3	3	9
Orientation for Solar	x		1	3	3	2	6
Energy Reduction: Hot Water & Appliances	x		1	3	3	1.7	5
Indoor Environmental Quality	x		2	3	3	1	3
Homeowner Education	x		1	3	3	0.5	1.5
LEED for Neighborhoods	x		1	2	3	0.5	1.5
Access to Open Space	x		2	3	3	0.5	1.5
Low VOC	x		2	3	3	0.5	1.5
Improved Durability	x		2	4	4	2	8
Reduced Disturbance / Tree Protection	x		2	3	3	1	3
Non Toxic Pest Control	x		1	5	5	3	15
Whole System Integrated Planning	x		2	4	4	1	4
TOTAL POINTS							**100**
% of Maximum Allowable			**100 points maximum**				**100.00%**

For the purposes of this report the authors are concerned only with those green building attributes that relate to energy and energy efficiency (highlighted above in green). Thus, we attempt to develop a proxy score based on HERS ratings and 4 other energy attributes – Energy Efficiency, On-site Renewable Energy, Orientation for Solar, and Energy Reduction. Our purpose is not to provide a definitive conclusion of value, but rather to share our experience of using this new underwriting standard and to compare its results with our energy modeling and life cycle costing work. As no public study has been produced yet in which the new underwriting standard is in this manner evaluated, we hope that this work does its part to help advance its usefulness and practice.

3.6 Limitations

This report has several limitations.

First, it was difficult to pinpoint some of the materials cost estimates. As previously noted, some prices came from RS Means CostWorks, the leading construction cost estimating tool, which provides data for local markets but is not always accurate. Others were looked up on-line from manufacturers' websites, with the average price in a range being used in some cases.

Second, the Life Cycle Costing analyses assume an annual discount rate of 5%, and three time horizons – 7, 15 and 30 years for calculating Net Present Value – which were chosen to map to the length of time typically spent in one house and two popular mortgage products. Homeowners' actual discount rates may vary and building lifetime may vary significantly from the time horizons chosen.

Third, given the proxy scoring system used to evaluate the LEED Silver, Gold and Platinum models, it is important to remember that these do not equate precisely to buildings that would obtain these certifications. Similarly, and in keeping with the goal of this research, the analysis drawing upon the Green Building Underwriting Standard is based on energy and energy efficiency attributes only. Also, the subjective scores assigned in the score sheet for three scenarios we evaluate are not independently verified; they have been assigned based on the collective knowledge of the Rutgers Center for Green Building.

Fourth, it is important to remember that the results are based entirely on models and formulaic projections. Thus, comparison of our results with the performances of actual energy-efficient homes would be a useful next step for evaluating the accuracy of the models and the robustness of our conclusions.

4 Results and Discussion

This section presents results of the energy modeling and life-cycle cost analyses. It considers several major categories of building upgrades and evaluates three or more different levels of effort within each category. For each scenario there is a brief description and a summary page of results.

The results page includes a chart comparing the baseline building and the scenario in terms of construction cost, operating cost, and net present value of total costs for time horizons of 7, 15, and 30 years. Seven years is the typical tenure of a homeowner in a particular house, 15 years is the length of a typical medium-term mortgage, and 30 years is the length of a typical long-term mortgage. An annual discount rate of 5% is used in this analysis to reflect the approximate cost of a mortgage in today's market. The life-cycle cost analysis tool employed here does not include replacement of equipment that wears out before the end of the specified time horizon, hence it slightly overstates the attractiveness of mechanical system upgrades. With the exception of the SRECs earned by the solar energy systems, it does not consider government subsidies or the influence of tax policies. Aside from the SRECs, all items included in the analysis are costs, hence, **the less costly scenario is preferable, all else equal**. Costs are shown as negative numbers on the graph.

The results page also includes a chart showing the percent difference between the net present value of total costs in the baseline and the scenario, respectively, for a time horizon of 15 years. **A negative number means that the scenario costs less than the baseline case, whereas a positive number means that it costs more.**

Each results page also includes a sensitivity analysis table showing the effects of future energy prices and various investment time horizons on the relative attractiveness of the baseline and scenario building designs. Again, a negative number means that the scenario costs less than the baseline case, whereas a positive number means that it costs more. If all of the entries in the table are negative, then the scenario outperforms the baseline case robustly across a variety of assumptions about the future. If some table entries are positive and some are negative, then the relative performance of the baseline and scenario are more contingent and sensitive to particular assumptions.

Following the scenario-specific discussion, there is a comparison of the range of scenarios considered within each major category of building upgrade. This comparison clarifies how cost-effective is each level of effort, and shows whether diminishing returns affect that category of building upgrade.

4.1 Envelope Upgrades

Framing and insulation are both important areas of focus when building an energy efficient single-family residential dwelling. For example, experts maintain that conventionally framed homes, such as the baseline model, typically use 20% more wood than is necessary to maintain the home's structural integrity (Johnston and Gibson). Incorporating advanced framing techniques (described in more detail below) that minimize air infiltration and the amount of materials used can result in large energy and cost savings, a double-win.

Choosing insulation types is a similarly important decision when building an energy efficient residential home. While fiberglass batts continue to be used the majority of the time, there are a growing number of other options available. Insulation is generally chosen by first considering two key factors: 1) what part of the home is being insulated, and 2) what the desired R-value is (DOE 2010).[35] Furthermore, while the Department of Energy produces a Code listing regional R-value recommendations for the various areas of a home, green building experts generally maintain that builders should aim for a 50 percent improvement in R-value over the prevailing building code. However, more is not always better, as there is a point of diminishing returns with insulation (i.e. the point at which the economic savings of using thicker insulation are outweighed by higher outlays).

Windows and exterior doors are other realms of home residential construction with possible efficiency gains. Windows and exterior doors are often areas of a home that allow for significant heat loss. However, great advances have been made in the types of energy efficient window and door products that are available.[36]

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[35] R-value is the accepted measure of thermal resistance for insulation. The higher the R-value, the more effective the insulation is. Each insulation type has as R-value per inch of thickness.

[36] Windows are also measured for their resistance to heat transfer, but their measurement is called a U-value. U-values are the inverse of R-values, so the lower the U-value, the more energy efficient the window is. At this point in time, window U-values range from 0.7, the most efficient, to 1.0, the U-value of plain glass (Johnston and Gibson).

Figure 6: Envelope Upgrades Component Assumptions

COMPONENT TYPE	**COMPONENT DESCRIPTION**	**R-VALUE**
Basic Framing/Insulation Upgrade		
Foundation Walls Insulation	Rigid Extruded Polystyrene	R-20
Frame Floor Insulation	Unfaced Fiberglass	R-30
Wall Joist Insulation	Fiberglass Batt	R-38
Ceiling Joist Insulation	Blown-In Cellulose	R-53
Above-Grade Walls	Rigid Foil-Faced Isocyanurate	R-28.8
Framing Materials	2 x 6 wood studs, 24" O.C., whole building	N/A
Enhanced Framing/Insulation Upgrade		
Foundation Walls Insulation	Insulated Concrete Form (ICF)	R-60 (+ R-3 ext.)
Frame Floor Insulation	Fiberglass (with Hardwood Floor)	R-49
Joist Insulation	Fiberglass Batt	R-38
Ceiling Joist Insulation	Blown-In Cellulose	R-70
Above-Grade Walls	Structural Insulated Panel (SIP)	R-40
Framing Materials	2 x 6 wood studs, 24" O.C., Ceiling, Roof and Floors	N/A
Window and Door Envelope Upgrade		
Windows	Triple-Glazed, Argon, Low-E	U=0.24 SHGC=0.17
Doors	Steel Polysterene	U=0.14 R=7.14

4.1.1 Basic Framing/Insulation Upgrade

The first framing and insulation envelope upgrade to our base model incorporates some advanced framing components and more efficient insulation. Advanced framing has two main purposes: 1) To eliminate unneeded wood in the framing structure, thus reducing waste and unnecessary costs to the buyer, and 2) To open up space for more insulation, thereby reducing annual heating costs and creating a more desirable living environment (Johnston and Gibson). Though advanced framing results in great savings without compromising the structural integrity of the house, the fact that it is different can make it difficult to find builders who are familiar and comfortable with these techniques.

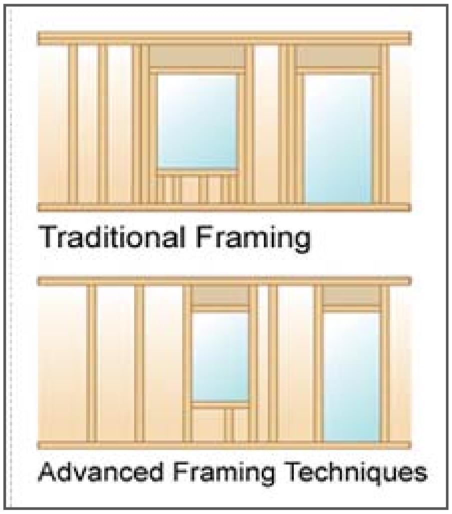

Figure 7: Traditional and Advanced Framing Techniques.
Source: www.greentexbuilders.com

This upgrade incorporates one of the key elements of advanced framing: changing the framing from 2x4 @ 16" on-center to 2x6 @ 24" on-center. This reduces the amount of wood needed and allows for the use of thicker, higher R-value, insulation.[37]

This model upgrade includes a number of insulation improvements as well. The foundation wall insulation is upgraded to an R-20 rigid extruded polysterene, a closed-cell foam insulation that begins as a molten substance and is then manufactured into easily usable sheets (DOE Polysterene

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[37] Though some builders use 2x6 framing on 16" center s, green experts recommend using 2x6 with 24" on-center for a more efficient envelope (Johnston and Gibson). The National Association of Home Builders also is supportive of 24" on center framing, and further suggests that it can be financially beneficial to create wall framing layout drawings to help guide the crew and prevent them from applying unnecessary studs (NAHB 2001).

Insulation Materials). With an R-value of 5 per inch, rigid extruded polysterene has traditionally been used to insulate below-grade due to its ability to keep moisture outside of wall cavities.[38]

Rigid foil-faced isocyanurate, another closed-cell member of the rigid foam insulation family, is used in the above-grade walls. As opposed to the average fiberglass batt R-value of 3-4 per inch, rigid isocyanurate has an R-value of 7 per inch. The foil facing serves as a moisture barrier. There is a potential limitation in using this type of insulation in that the R-value of isocyanurate material can drop as some of the gas escapes and air replaces it, an occurrence known as "thermal drift" (DOE 2010 Polyisocyanurate Insulation Materials). The drop in R-value will generally occur within the first two years after manufacturing, if at all, and then the R-value should remain stable throughout the duration of its lifespan.

Because the baseline model has wall joist insulation with an already high R-value, the same R-38 fiberglass batt joist insulation is used in this upgrade. The ceiling, however, is the area that should have the highest R-Value. The ceiling insulation in this upgrade is cellulose, a material made from recycled newspaper. While comparable in cost to fiberglass, cellulose has the higher R-value of the two. Industry experts argue that cellulose is much better for the environment because it is made from recycled content, has low toxicity, and it uses less energy to manufacture.[39]

As illustrated in Figure 8, the basic framing and insulation upgrade costs significantly LESS in initial investment ($19k, or 19%) as compared to the baseline. This same upgrade saves approximately $300, or 9% in annual operating costs. The NPV analyses at 7, 15 and 30-year intervals all demonstrate that this upgrade is a better investment than the baseline model saving, respectively, 17, 16 and 15%. As demonstrated in the sensitivity analyses, the savings become somewhat greater with increasing energy costs, as would be expected.

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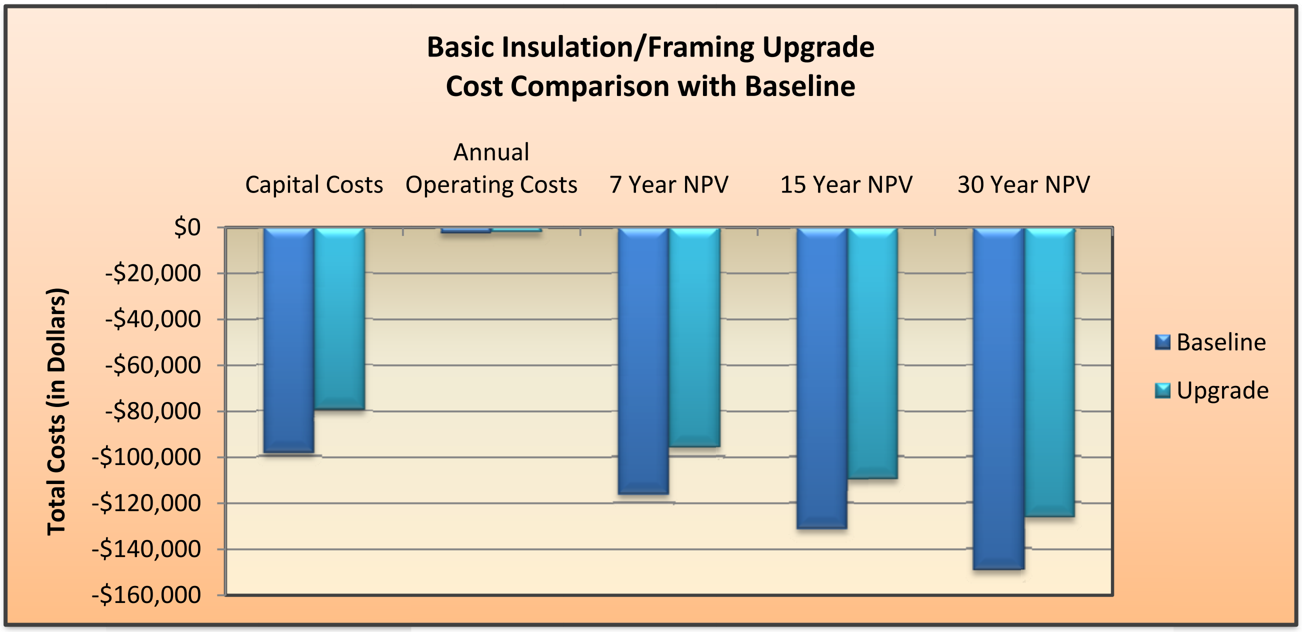
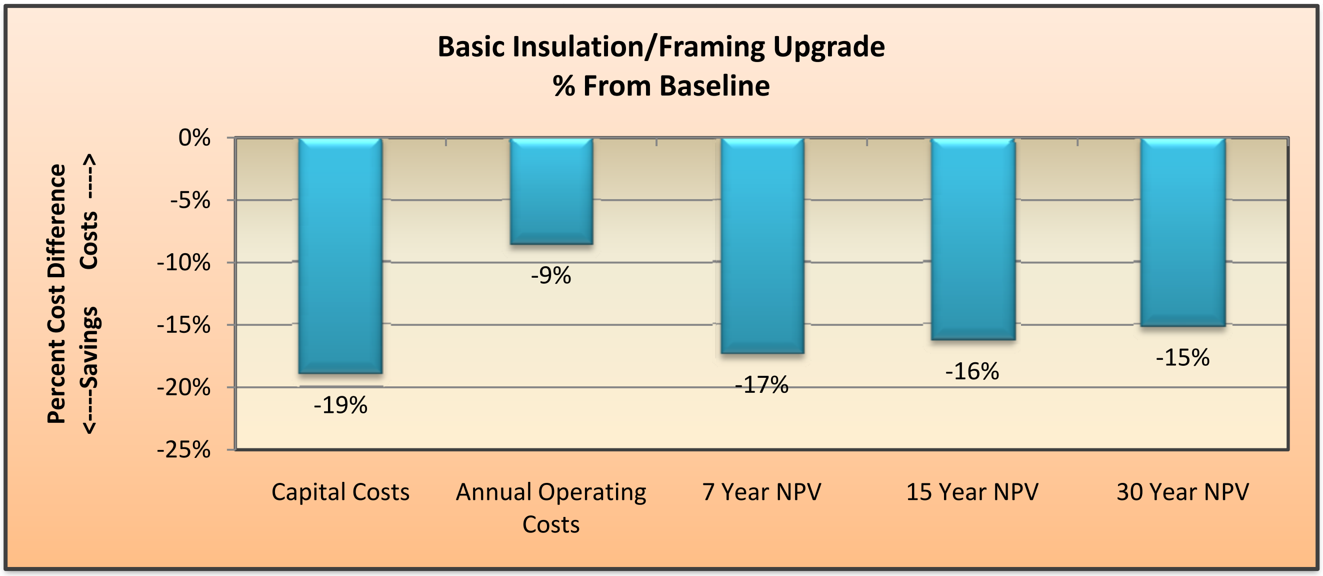
[38] Johnson and Gibson, op cit.

[39] The Cellulose Insulation Manufacturer's Association claims that, because fiberglass and other mineral fiber insulation are manufactured in gas-fired furnaces, it takes 20-200 times more energy to produce fiberglass than cellulose (CIMA).

Figure 8: Life Cycle Cost Analysis for Basic Framing/Insulation Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	-17%	-17%	-18%
15 Year NPV	-16%	-16%	-17%
30 Year NPV	-15%	-15%	-16%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.1.2 Enhanced Framing/Insulation Upgrade

A more efficient framing and insulation upgrade uses other green technologies. Insulated Concrete Forms (ICFs) insulate the foundation wall. ICFs are an important green product that combines insulation and concrete to create well-insulated foundation walls. Made of interconnected foam boards that are joined together with plastic ties, ICFs can also serve as a backing for drywall on the inside of a home's foundation (DOE Insulating Concrete Forms). However, ICFs' outside foam can make them susceptible to insect infestations and moisture leakage; thus, they should be covered in some sort of insecticide and waterproof membrane to minimize the likelihood of such occurrences.[40]

Structural insulated panels (SIPs) are used in the above-grade walls. SIPs are somewhat similar to ICFs in that they provide insulation and structure in one unit. SIPs are boards that are made with oriented strand board and insulting foam. They are manufactured completely off-site, which lends itself to a very quick construction process and the realization of labor costs far below those for conventional framing. The quick construction process is particularly advantageous in cold climates because as soon as the SIPs go up, there is an insulated space in which laborers can work comfortably and productively. SIPs are generally custom-made and sized for a specific home; therefore, extreme care and attention to detail are more critical with this type of wall structure than with a conventionally framed dwelling. However, assuming that SIPs are installed correctly, they can offer extraordinary energy savings as they permit practically no air infiltration. Some of the concerns with using SIPs include possible fire hazards (which can be addressed by using SIPs that have a fire retardant coating outside of the board's interior), insect infestations (often addressed by applying insecticide and minimizing humidity levels within the home), and the need for a well-designed and high-quality air ventilation system to provide sufficient ventilation given the extremely airtight structure (DOE Structural Insulated Panels). Figure 9 and 10 show two images of SIPs.

Lastly, this model has upgraded ceiling insulation of R-70 blown-in cellulose. And, the floor insulation is fiberglass, as in the baseline, but with a higher R-value of 49.

As seen in Figure 11, the more efficient framing and insulation upgrade package actually also costs slightly less in initial investment ($ 1k) as compared to the baseline and saves approximately $500, or

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[40] The costs of insecticide and moisture repellent are not included in the cost analyses presented in this report.

16% in annual operating costs. The NPV analyses at 7, 15 and 30-year intervals all demonstrate that this upgrade is a better investment than the baseline saving, respectively, 3, 5 and 6%. As demonstrated in the sensitivity analyses, the savings become somewhat greater with increasing energy costs, as would be expected.

Figure 9: Structural Insulated Panel Detail.
Source: www.universalcontructionfoam.com

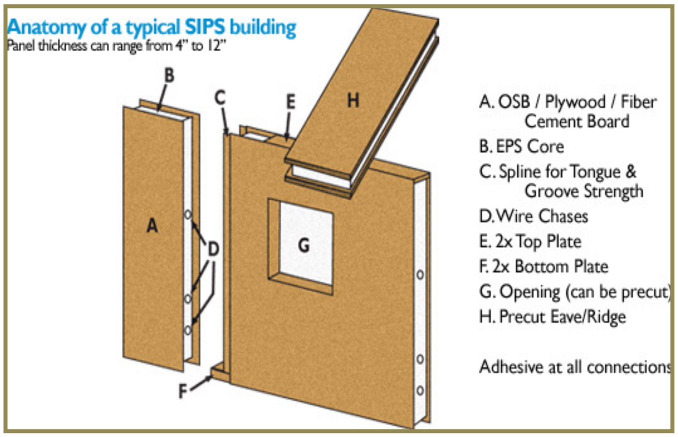
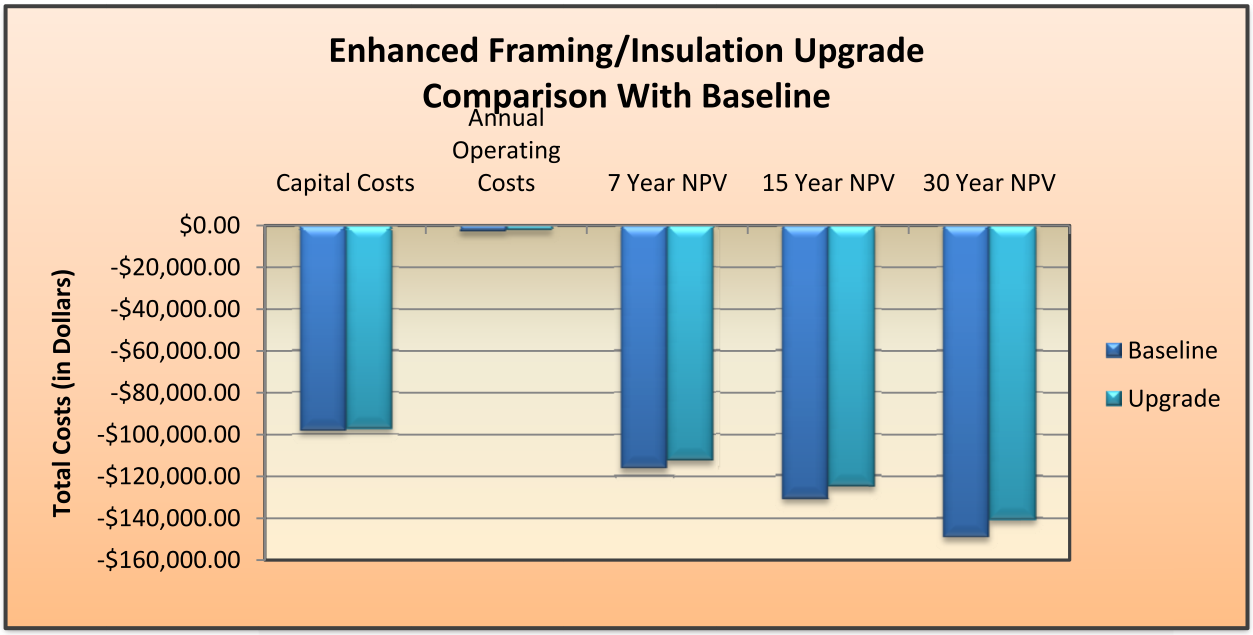
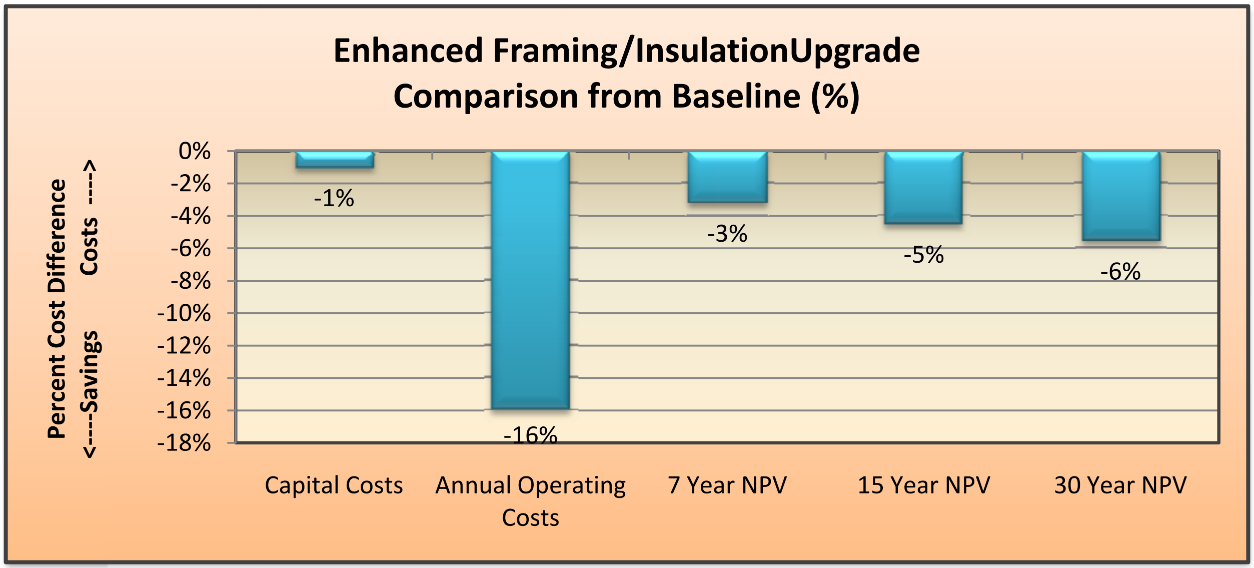


Figure 10: Structural Insulated Assembly.
Source: www.thehomeenerycompany.com

Figure 11: Life Cycle Cost Analysis for Enhanced Framing/Insulation Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	-3%	-3%	-4%
15 Year NPV	-5%	-5%	-5%
30 Year NPV	-6%	-6%	-8%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.1.3 Door and Window Upgrade

The third envelope upgrade includes more efficient windows and doors. It uses well-insulated exterior doors given their assumed ability to improve a home's energy efficiency. Storm doors are not included because, although they may increase a door's insulation, adding them to an already high efficiency insulated door has been found to not be cost effective. The upgraded doors have a U-value of 0.14 and a R-value of 7.14.

In addition to the U-value, the Solar Heat Gain Coefficient (SHGC) is another indicator of a window's efficiency. The SHGC is a number between 0 and 1 that indicates the amount of solar heat that passes through a window. According to the Department of the Energy, windows in New Jersey should have an SHGC below 0.30 in the Northern zone and below 0.40 in the North-Central zone (Energy Efficiency Collaborative). Another study further shows that placing windows with an SHGC greater than 0.26 in south facing windows and using a lower SGHC, below 0.25, in east and west facing windows enhances energy efficient performance. In this upgrade, the windows are changed to triple-glazed, argon, low-e windows and the doors are changed to steel polysterene doors. The upgraded windows have a U-value of 0.24 and a SHGC of 0.17.

As seen in Figure 12, the more efficient door and window package requires just over $4k more in initial investment than the baseline door and window components.[41] However, the upgraded model saves approximately $300, or 11% in annual operating costs. The initial upfront costs for the upgraded doors and windows will be paid back within 14 years. While the NPV after 7 and 15 years shows the baseline door and windows to be the better investment, when considering a longer 30-year period, the more efficient door and window package becomes slightly more financially desirable. Yet, even after 30 years, the door and window upgrades only save just under 1%. These results suggest that this combination of green technologies is not the most economically advantageous.

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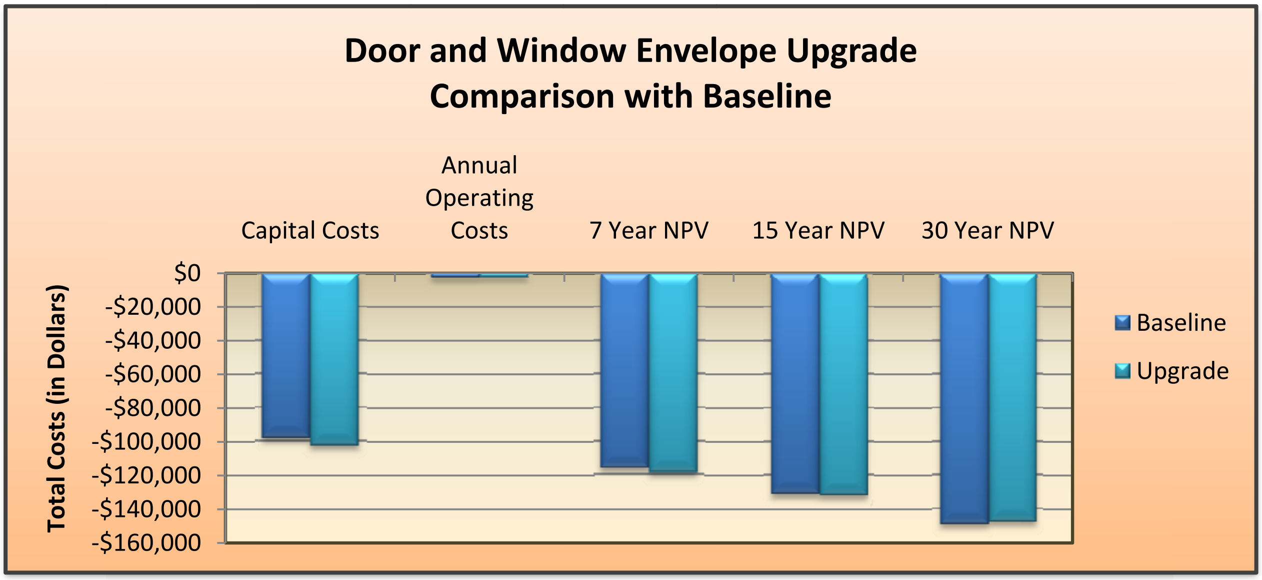
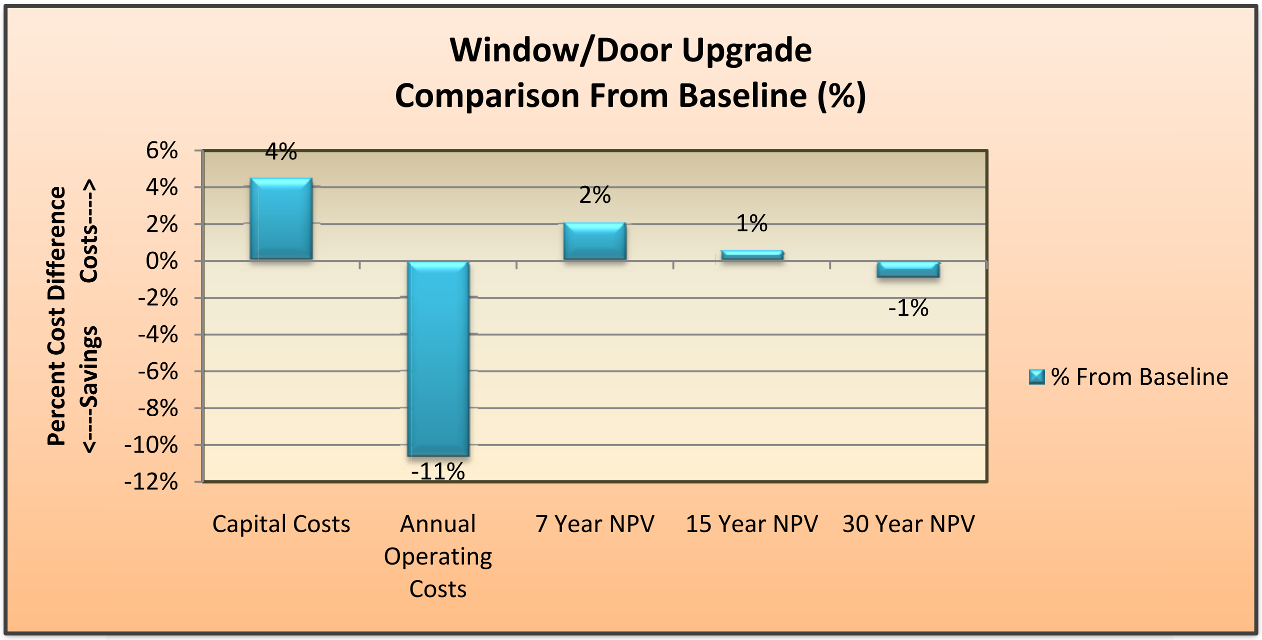
[41] The door and window capital costs were derived from quotes from local vendors.

Figure 12: Life Cycle Cost Analysis for Door and Window Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

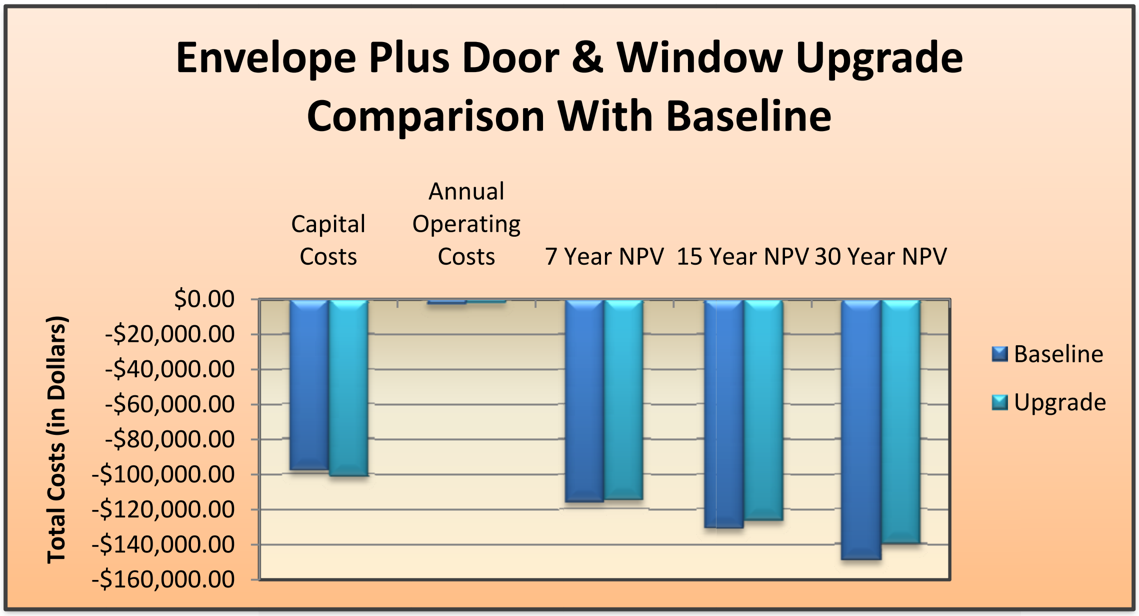
Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	2%	2%	2%
15 Year NPV	1%	1%	0%
30 Year NPV	0%	-1%	-2%

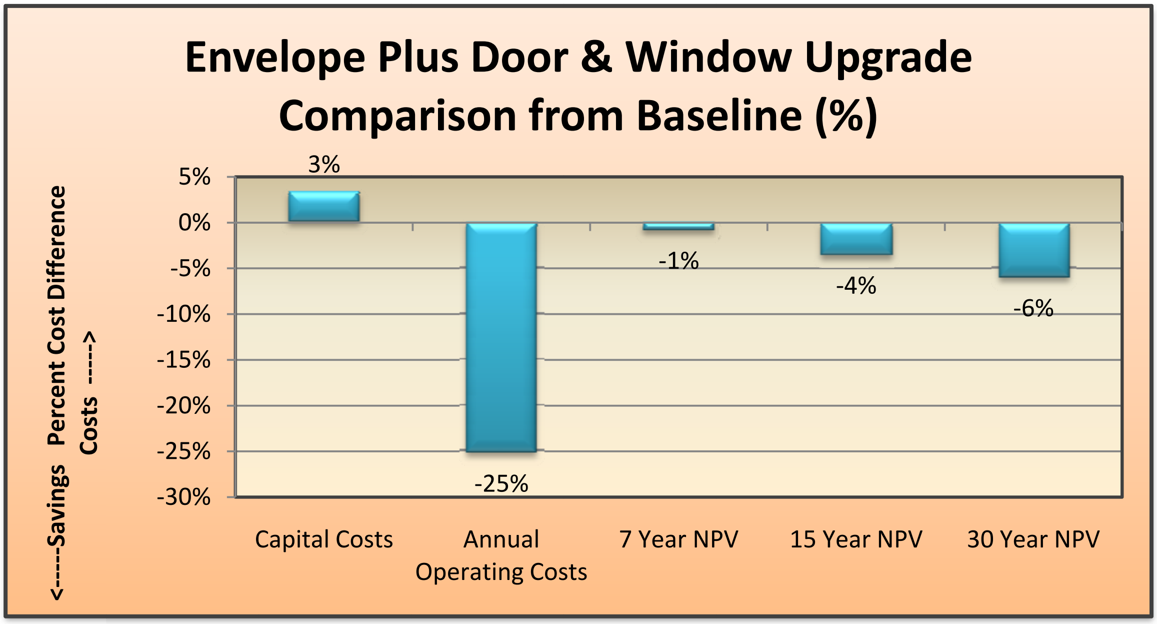
Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.1.4 Enhanced Plus Door and Window Upgrade

As seen in Figure 13, adding the higher efficiency doors and windows to the enhanced framing and insulation upgrade yields a design that costs about $3k more to build than the baseline case but saves about $750 per year in operating costs. NPVs favor the upgrade. However, when compared to the enhanced framing and insulation upgrade absent the higher performance doors and windows, the more aggressive scenario delivers diminishing returns at the margin. The more efficient doors and windows add more than $4k to capital costs of the enhanced upgrade bundle, but the reduction in annual operating costs is smaller per additional dollar invested. Furthermore, the NPV calculations reveal that the enhanced upgrade model remains more cost-effective without the higher efficiency doors and windows over 7 and 15 year time horizons. These results reinforce the previous findings that, provided the baseline home already contains reasonably energy-efficient windows and doors, the even higher efficiency window and door components in this upgrade are probably not the green products that will provide the most economic benefit at the investment margin, although they do not impose net losses.

Figure 13: Life Cycle Cost Analysis for Enhanced Plus Door and Window Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	-1%	-1%	-1%
15 Year NPV	-3%	-4%	-5%
30 Year NPV	-5%	-6%	-9%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.1.5 Summary Results

Modeling these various envelope upgrade scenarios produces a number of interesting findings. As seen in the following two charts, applying more efficient framing and insulation to the conventional baseline model results in a decrease in annual operating costs as well as long-term cost-savings. While this is true for both the basic and enhanced upgrade, the basic upgrade has the lowest construction costs and is the most cost-effective option over time.

The key component of the basic upgrade's cost-effectiveness is the shift from 2x4 @16" on-center to 2x6 @ 24 " on-center framing, one of the key components of Advanced Framing methods discussed earlier. This change alone results in almost $20k in material and labor capital cost savings. This framing not only saves up-front material and labor costs, it also reduces annual operating costs by 9% because it allows for the use of thicker, higher R-value insulation. Some builders may be unfamiliar with these techniques, and thus resistant to using them; however, adopting advanced framing techniques is one of the most economically beneficial green investments in new residential construction.

Regarding the enhanced upgrade, the use of structural insulated panels and very high R-value insulation provides 16% greater savings in annual operating costs. Even though the SIPS have very expensive material costs, their reduced labor costs, combined with the savings of changing the floors, roof and ceiling to 2x6 @24" on-center framing, makes the construction costs for this upgrade almost exactly the same as those for the far less energy efficient baseline model. Thus, the investment in energy efficiency pays for itself at the time of construction. The enhanced upgrade is more cost-effective than the baseline model, but it is $18k more expensive than the basic upgrade at the time of construction, and it remains less cost-effective over a 30-year period.

The door and window upgrades do not add as much value as those for framing and insulation. Incremental initial costs are much higher and offsetting energy savings are much lower, and they perform less well in net present value terms for all three time horizons studied.

However, as a hedge against high energy prices, the more aggressive envelope strategies may be worthwhile investments for many homeowners. Additionally, there are often benefits in the form of increased comfort and daylight access associated with these envelope strategies.

Figure 14: Cost Comparison of Envelope Upgrades and Baseline

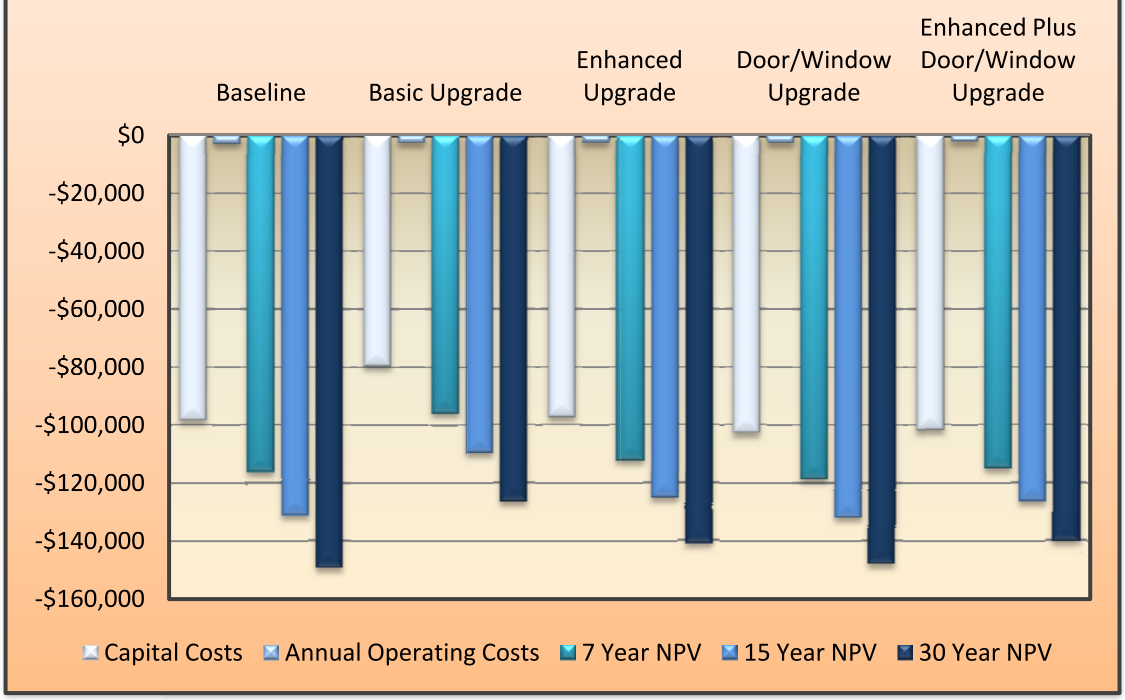
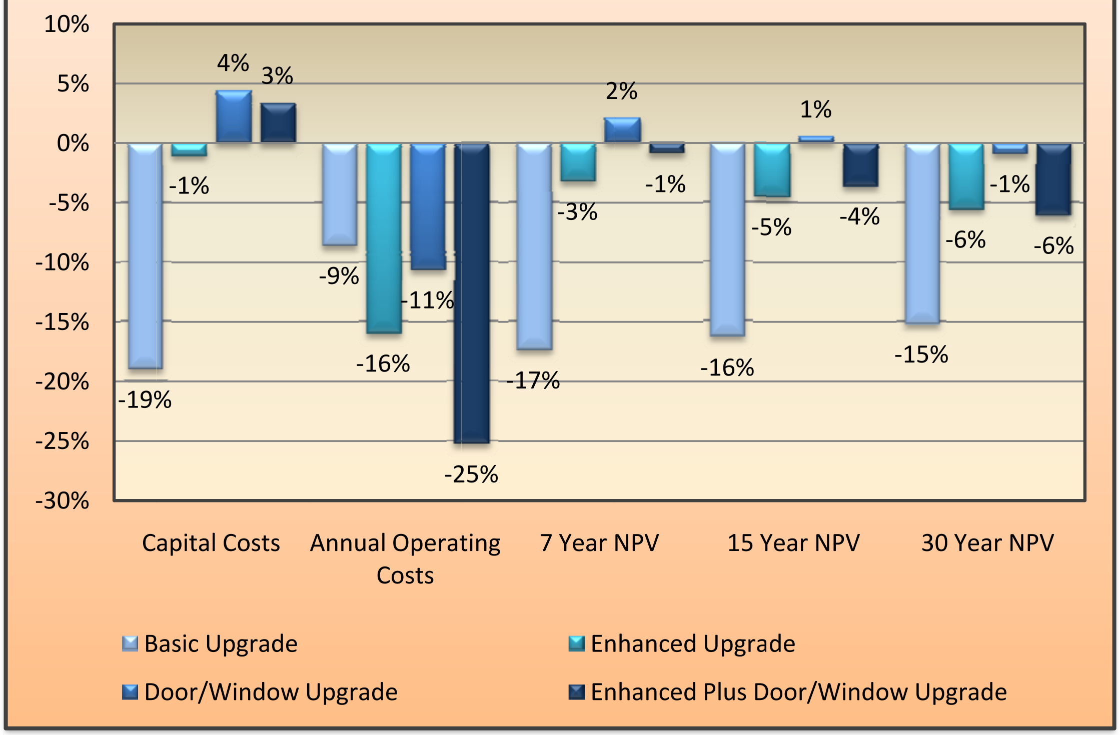


Figure 15: Percent Cost Divergence of Envelope Upgrades from Baseline



4.2 Active Mechanical Systems

A building's active mechanical systems deliver heating, air-conditioning and ventilation (HVAC) to ensure thermal comfort. HVAC systems are typically areas of residential home construction with both high capital and annual operating costs. However, the fact that these interrelated systems are often inefficient and improperly sized means that there is a lot of opportunity for cost and energy savings by turning to greener, more appropriately-sized, HVAC options. When designed in conjunction with passive solar features, a home's heating and cooling loads can be reduced by 30-50%.[42] This section compares three mechanical system upgrades that achieve increasing levels of energy efficiency.

Figure 16: Active Mechanical Upgrades Component Assumptions

Component Type	**Component Description**	**Efficiency Level**
Low Level Upgrade		
Heating	Furnace 48 KBTU	94% AFU
Cooling	A/C Unit	14 SEER
Hot Water Heater	Demand Natural Gas	90% Efficiency
Mid Level Upgrade		
Heating	Hydronic Boiler 48 kbtu	95% AFU
Cooling	A/C Unit	18 SEER
Hot Water Heater	Demand Natural Gas	90% Efficiency
High Level Upgrade		
Heating	Ground Source Heat Pump, 5 Ton	4.0 COP
Cooling	A/C unit	13 SEER
Hot Water Heater	Demand Natural Gas	90% Efficiency

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[42] Johnston and Gibson, op.cit.

4.2.1 Low Level Mechanical Upgrade

The first active mechanical upgrade uses a higher efficiency furnace than that in the baseline model. A furnace's efficiency is indicated by its Average Fuel Efficiency Utilization (AFU) rate. Most conventional furnaces have an average AFU around 80%, meaning that approximately 20% of the fuel is wasted; however, experts recommend using a unit with an AFU of 90% or higher.[43] While the baseline model's furnace operated at 80% AFU, the low level upgrade uses a higher efficiency 94% AFU furnace.

This upgrade also utilizes a higher efficiency air conditioning system. Cooling systems also have their own efficiency rating, which is called the Seasonal Energy Efficiency Ratio (SEER). Government regulations now require a minimum SEER of 13 in all non-window units, but the higher the SEER is beyond 13 the greater the energy and cost savings will be (Johnston and Gibson). While the baseline model uses a standard 13 SEER air conditioning unit, a 14 SEER is used in the low level upgrade.

This upgrade also uses a natural gas-fired demand hot water heating system. These heaters are more efficient than standard water heaters because they do not require the use of a storage tank (U.S. DOE *Demand Water Heaters*).

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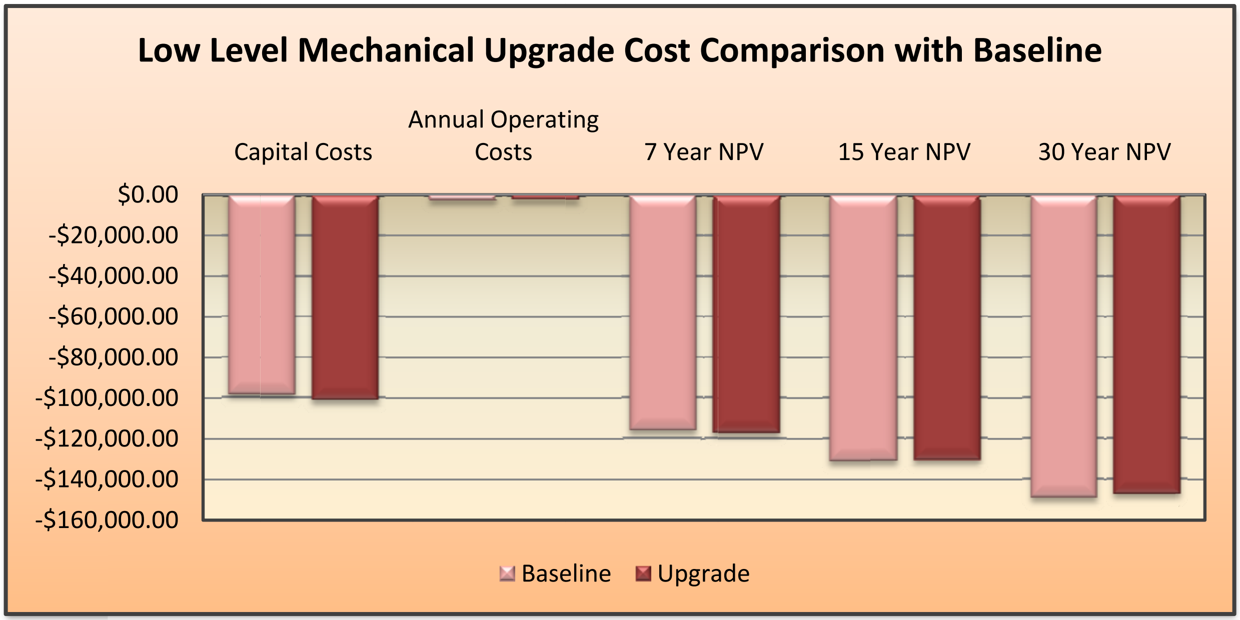
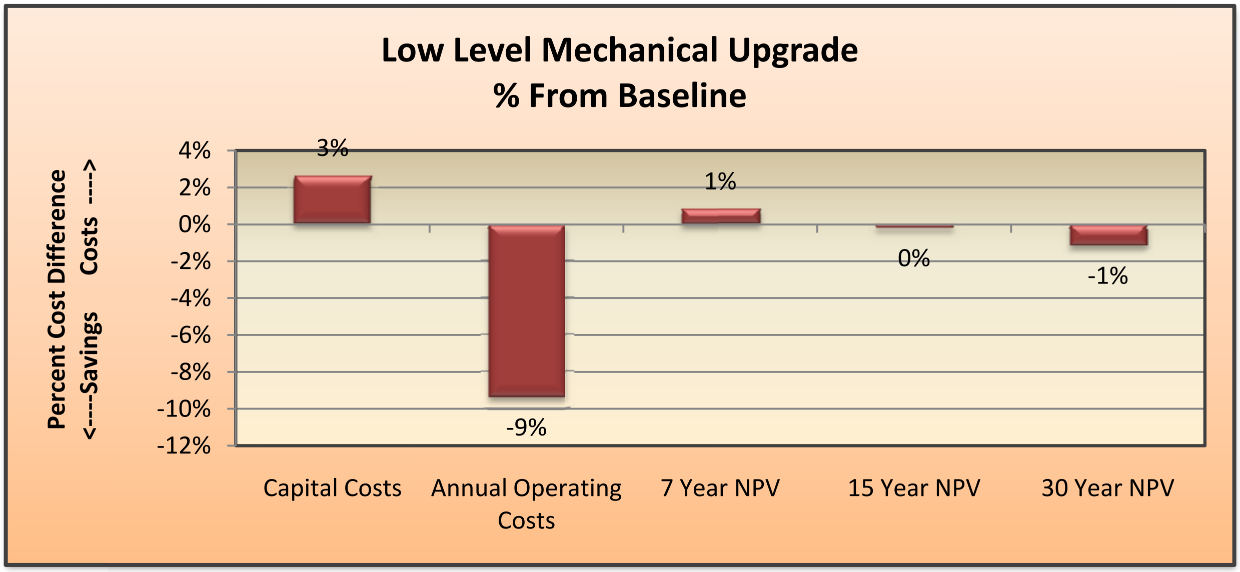
[43] Johnston, David, and Scott Gibson. 2008. *Green from the Ground Up*, Newtown, CT: Taunton Press, pp. 173-196.

Figure 17: Life Cycle Cost Analysis for Low Level Mechanical Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

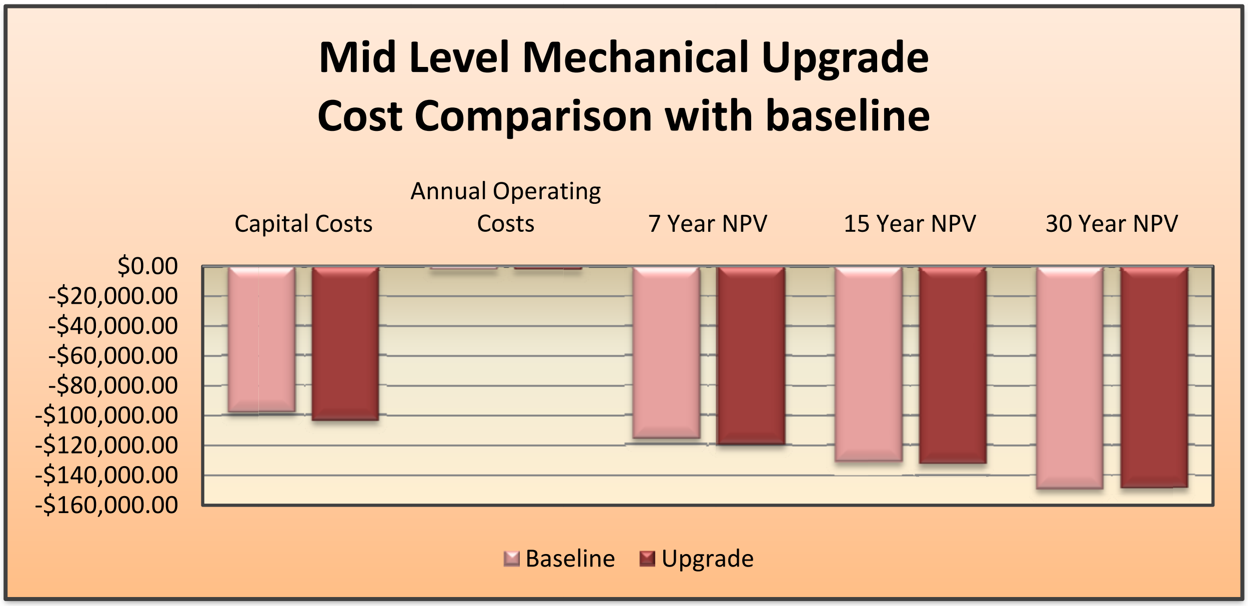
Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	1%	1%	1%
15 Year NPV	0%	0%	-1%
30 Year NPV	-1%	-1%	-2%

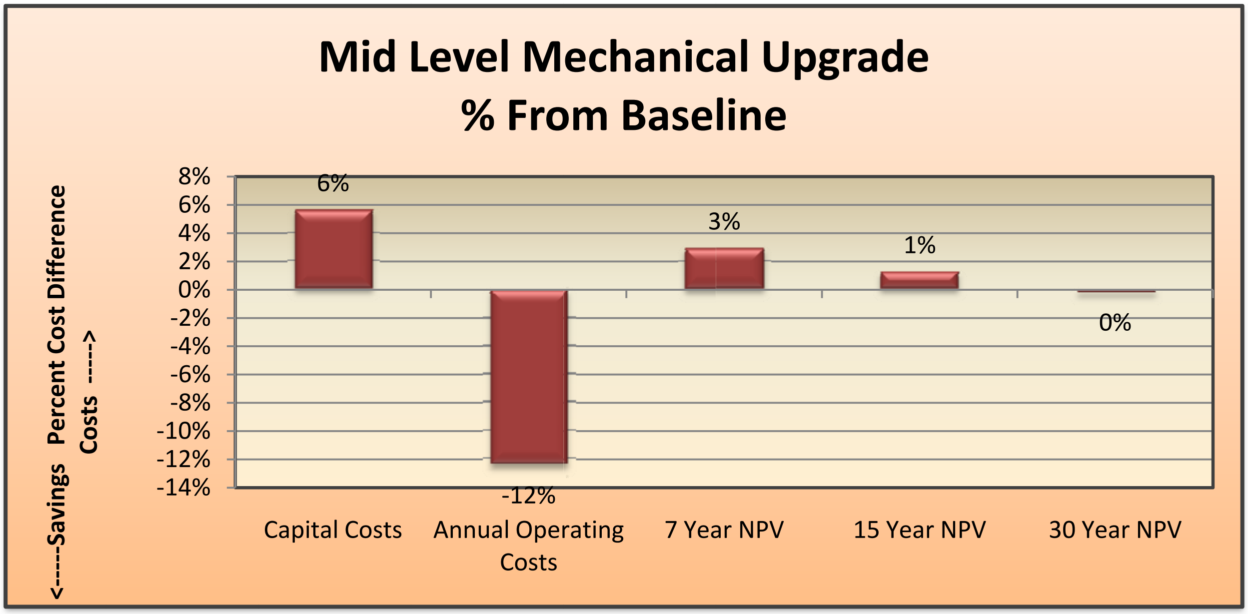
Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.2.2 Mid Level Mechanical Upgrade

The second active mechanical upgrade uses even more efficient heating and cooling systems. It uses a 95% AFU hydronic heating boiler rather than a furnace, and an 18 SEER air conditioning unit instead of a 13 SEER. A residential hydronic boiler produces hot water that can be pumped to hot water coils in air handlers. It can be distributed throughout the home via radiators, baseboard heating, or radiant floor heating. Much of a hydronic boiler's efficiency gains come from the fact that when it is piped to individual rooms, each room has a valve working off of a thermostat so that the heat can be locally adjusted as needed. This upgrade also uses the demand hot water heater.

Figure 18: Life Cycle Cost Analysis for Mid Level Mechanical Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	3%	3%	3%
15 Year NPV	1%	1%	1%
30 Year NPV	0%	0%	-2%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.2.3 High Level Mechanical Upgrade

The final and most rigorous active mechanical upgrade uses a ground source heat pump, also known as a geothermal system (See Figure 21). This type of system uses the uniform temperature of the earth (55°) as a thermal reservoir to make heating and cooling more efficient. It circulates water containing a sealed refrigerant through a chamber of pipes that ultimately flows through a heat exchanger. With the use of a de-superheater, hot water can be produced from wasted heat in the winter and produced free as a byproduct of the thermal process in the summer when it is in cool mode. Well fields can be installed in either vertical or horizontal trenches depending on the existing soil conditions. If there is a high level of bed rock, then vertical trenching is preferred, which requires boring and can be more expensive.

Ground source heat pump systems can have either an open or a closed loop. An open loop utilizes water from an existing source of water, while a closed system does not. Although an open-loop system is less expensive to install, a closed loop system was assumed in the upgrade because it has fewer maintenance and permitting problems, and does not require that a building be located near a water source. Several additional variables to consider when using this type of active mechanical system include soil type and the type of antifreeze used to prevent the water from freezing. Also, they are very expensive to install.

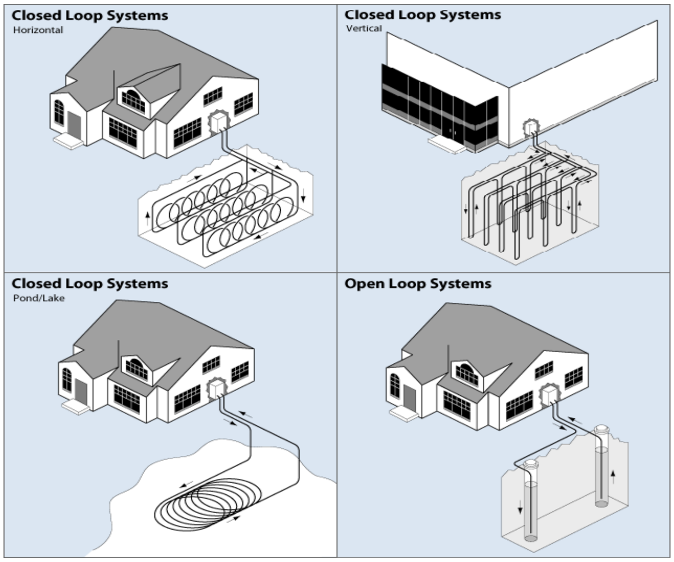
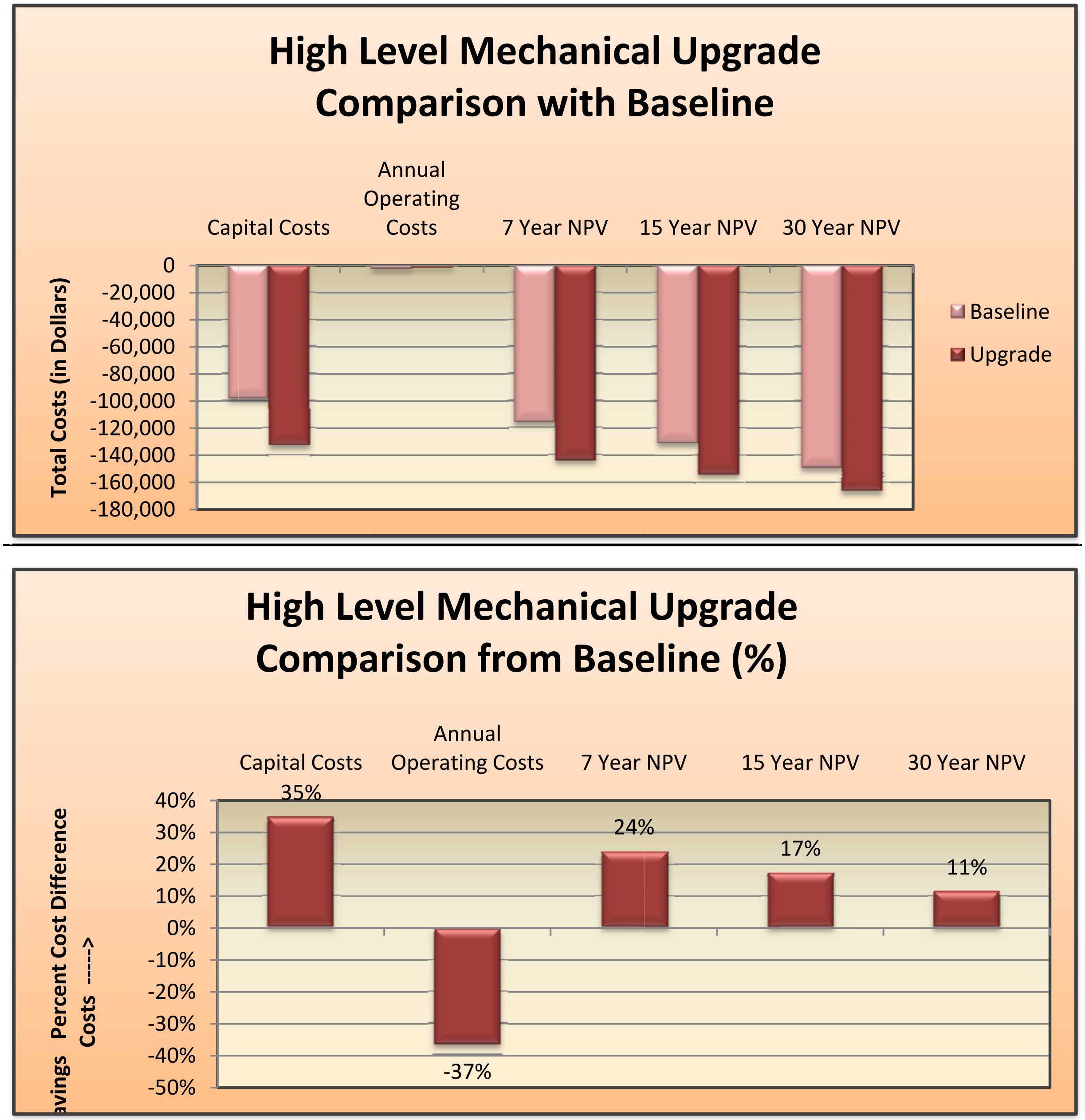


Figure 19: Geothermal Heat Pump Systems with Associated Equipment.
Source:
http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12650

Figure 20: Life Cycle Cost Analysis for High Level Mechanical Upgrade



Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	24%	24%	24%
15 Year NPV	18%	17%	15%
30 Year NPV	12%	11%	7%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

4.2.4 Summary Results

As seen in the following Figures 22 and 23, all three of the more energy efficient upgrades result in lower annual operating costs than the baseline model's conventional HVAC system. However, none of them delivers dramatic life-cycle cost savings because they incur higher initial costs.

The low-level furnace upgrade is a more attractive long-term investment than the baseline's conventional HVAC option. With capital costs around $3k more than the less efficient HVAC system, it reduces annual operating costs by about $300, achieving simple payback within 14 years.

The components of the mid level upgrade, including the 95% AFU hydronic boiler and the 18 SEER air conditioning unit, are less attractive investments than either the baseline case or the low-level upgrade. These improvements add about $5k in costs at the time of construction, and this amount is not paid back for 15 years.

In regards to the geothermal upgrade, the upfront capital costs for this system, which includes trenching, piping, equipment (including pump and de-superheater with associated fittings, valves, and backflow preventers), and installation, are very steep.[44] The incremental capital cost for this upgrade was over $34k,[45] thus surpassing the baseline capital costs by more than one-third. However, this type of system is one of the most eco-friendly and energy efficient; in fact, the annual operating costs decrease by 37% by changing the baseline's inefficient HVAC system to a ground source heat pump approach. Given the ground source heat pump's efficiency in operating costs, the steep upfront investment will not be recovered for 32 years. The geothermal model does become more cost-effective over time, yet even after a 30-year period the net present value is still 11% higher than the baseline model. This equipment is unlikely to pay for itself during its expected lifetime, absent tax benefits, unless the site permits a low-cost installation.

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[44] The geothermal ground source heat pump material and labor costs were derived as averages of estimates from local vendors.

[45] Costs for ground source heat pump well fields are highly site-specific. The reported construction cost is for a site that requires vertical boreholes. A site that is suitable for a shallow, horizontal piping loop may have an incremental cost of less than $10k. Such a system would achieve simple payback in less than 10 years (instead of 32 years for the vertical case).

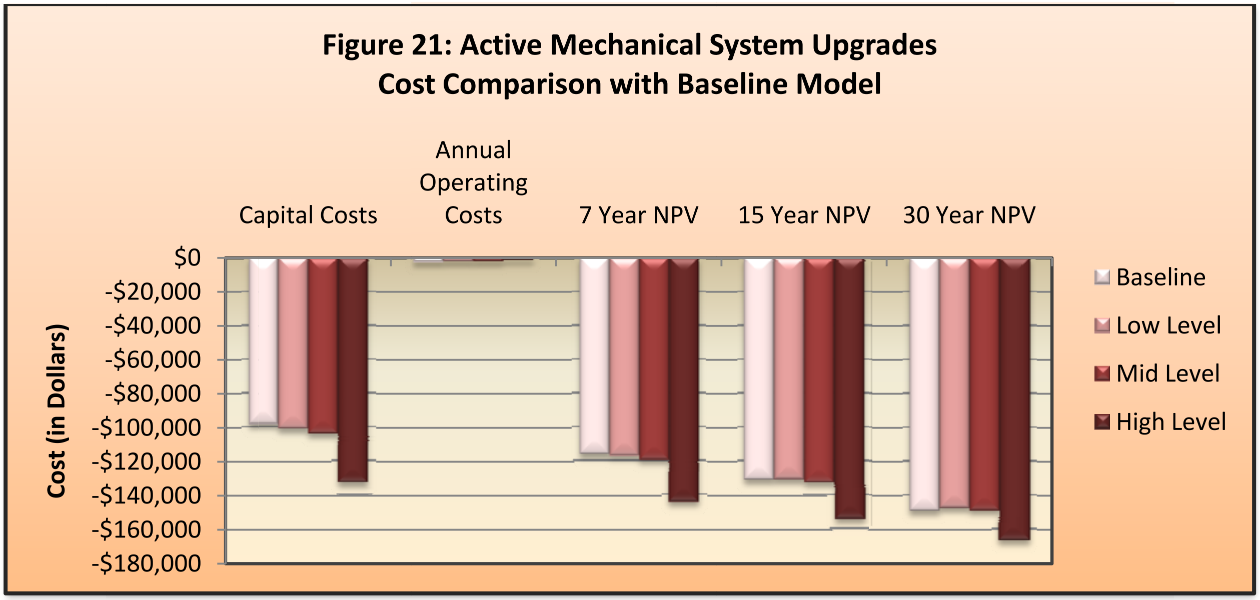


Figure 21: Active Mechanical System Upgrades Cost Comparison with Baseline Model

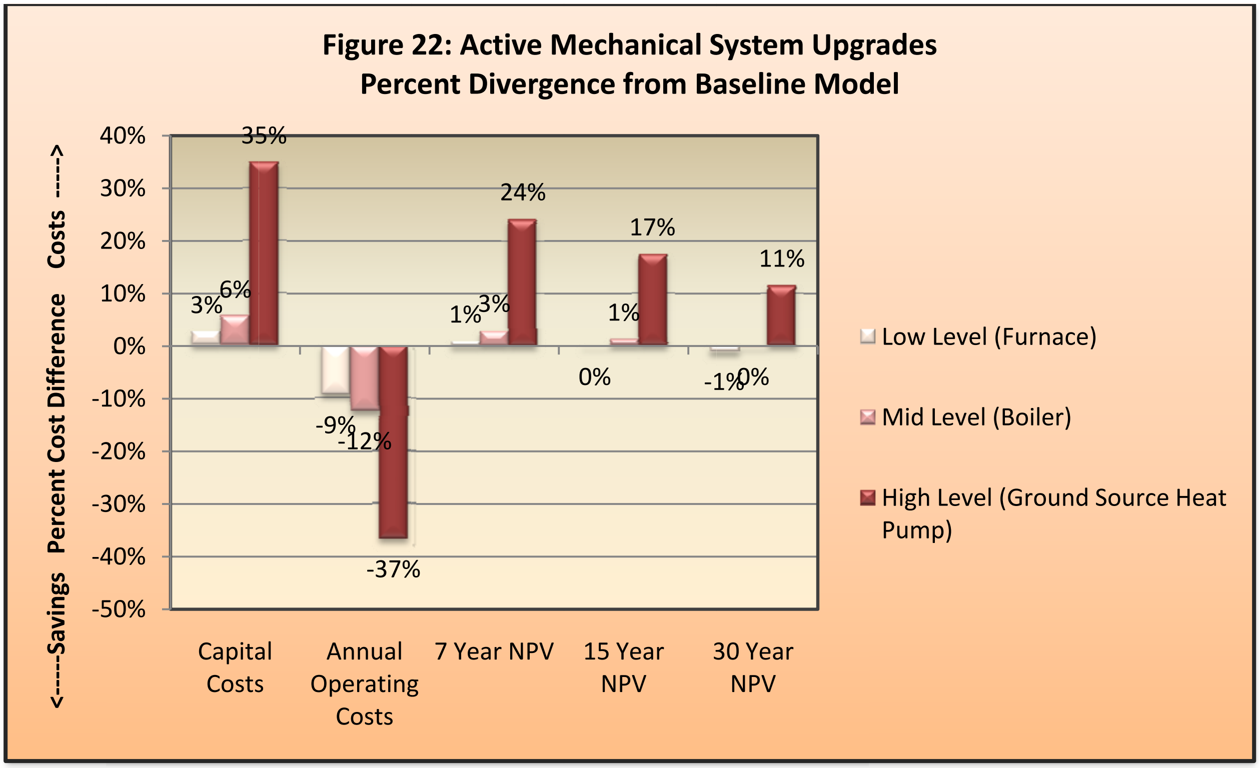


Figure 22: Active Mechanical System Upgrades Percent Divergence from Baseline Model

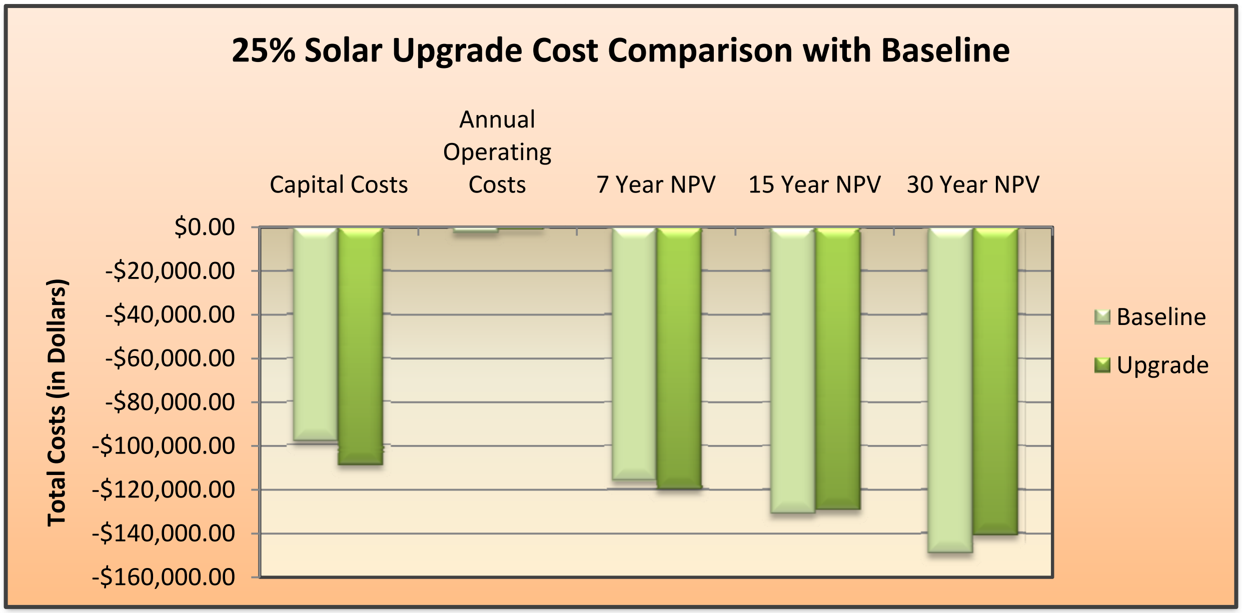
4.3 Solar Upgrades

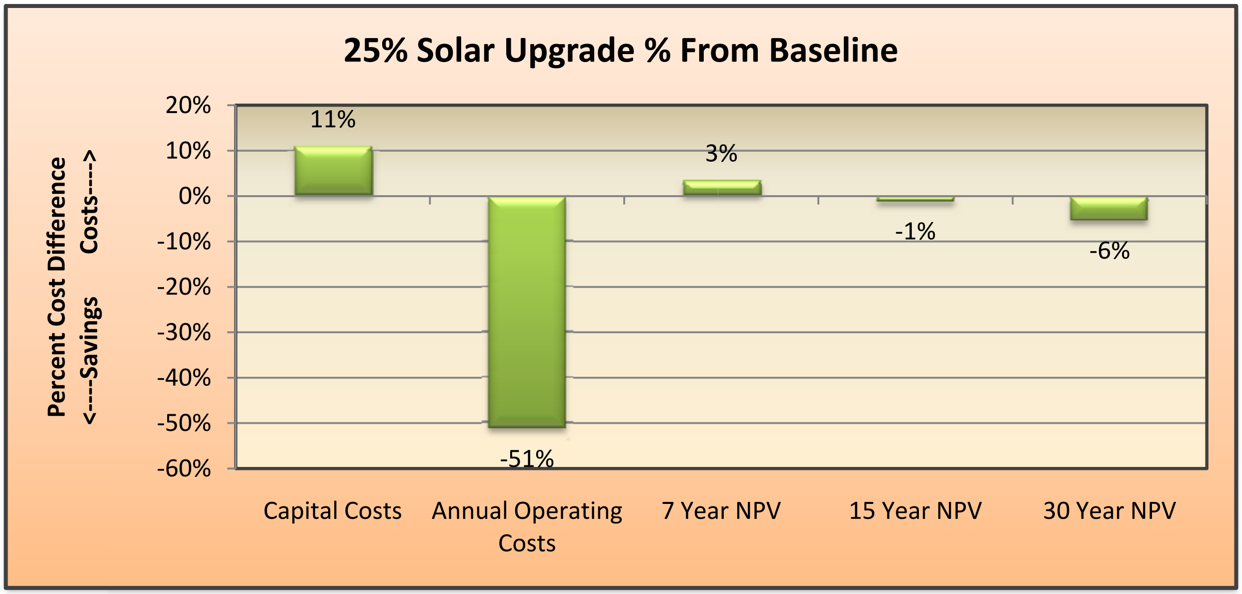
Photovoltaic (PV) systems convert the sun's energy, solar radiation, into usable, direct current (DC) electrical power, The PV panels that can be used in this process come in various forms including monocrystalline silicon, polycrystalline silicon and thin-film. The panels used for solar hot water heating are structurally different from those used for photovoltaic energy and, at this point in time, substantially lower in cost. The PV model developed for this study is grid connected, meaning it does not require the use of a backup battery. Solar water heating is not included in these scenarios.

It is important to note that only homes with passive solar design, including south facing glass, use of overhangs and natural shade, sufficient natural ventilation, and relatively low heating and cooling loads, should invest in solar panels (Johnston and Gibson). Assuming that these passive elements have been designed into a home, active PV solar panels can be an excellent and long-term cost efficient investment. This result is in large part due to the current high value of SRECS – Solar Renewable Energy Credits – in the State of N.J. and also a federal tax credit available for residential solar investment. The baseline in this study does not contain any solar elements; it relies upon traditional energy and heating sources. All of the PV solar upgrade models, below, use 10 watts per square foot and assume a cost of $6.00 per watt, as input by local experts. They further assume a sound passive design and a solar array located at 20 degrees on a southern exposure. The first solar upgrade uses a 180 square foot array, thus producing 1,985 kWh, or one-quarter, of the household's electric consumption. The second solar upgrade has an array twice as large, thus producing one-half of the household's electric consumption. The third upgrade is what is considered a "Net-zero" house in that its 720 square foot array produces 7940 kWh, the full amount of the household's electric consumption.

As Figures 24, 25, and 26 demonstrate, the capital costs for all three PV solar options are quite steep, adding $ 11k, $22k, and $ 43k to the cost of the baseline building, respectively. However, the annual operating costs are far lower, reducing operating costs by 51% from the baseline in the 25% solar upgrade case, and by more than 100% in the other two cases. In other words, because of the value of SRECs, the two larger solar arrays deliver net operating **revenues**, not costs. Despite the steep upfront investment, the NPV calculations reveal that within a 15 year time period, even a minimal investment in a small solar array proves to be viable given current SREC values. In all three models the payback period is 7 years. If the value of SRECs drops to levels seen in other U.S. states ($250 instead of the current $579 in New Jersey), then the simple payback period lengthens to 12 years. This is because the increased capital construction costs for the sequentially larger arrays is directly proportional to the resulting change in operating costs. Even absent the incentives from SRECs, the solar investment fully pays for itself within the period of a standard 30-year mortgage.

Figure 23: Life Cycle Cost Analysis for 25% Solar Upgrade



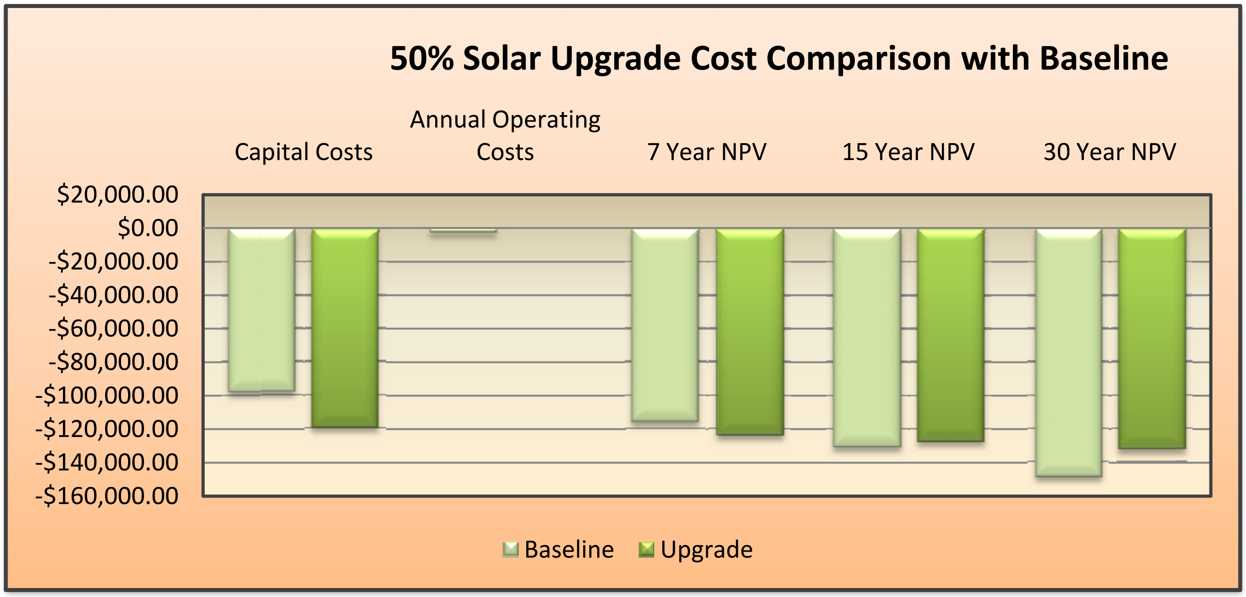


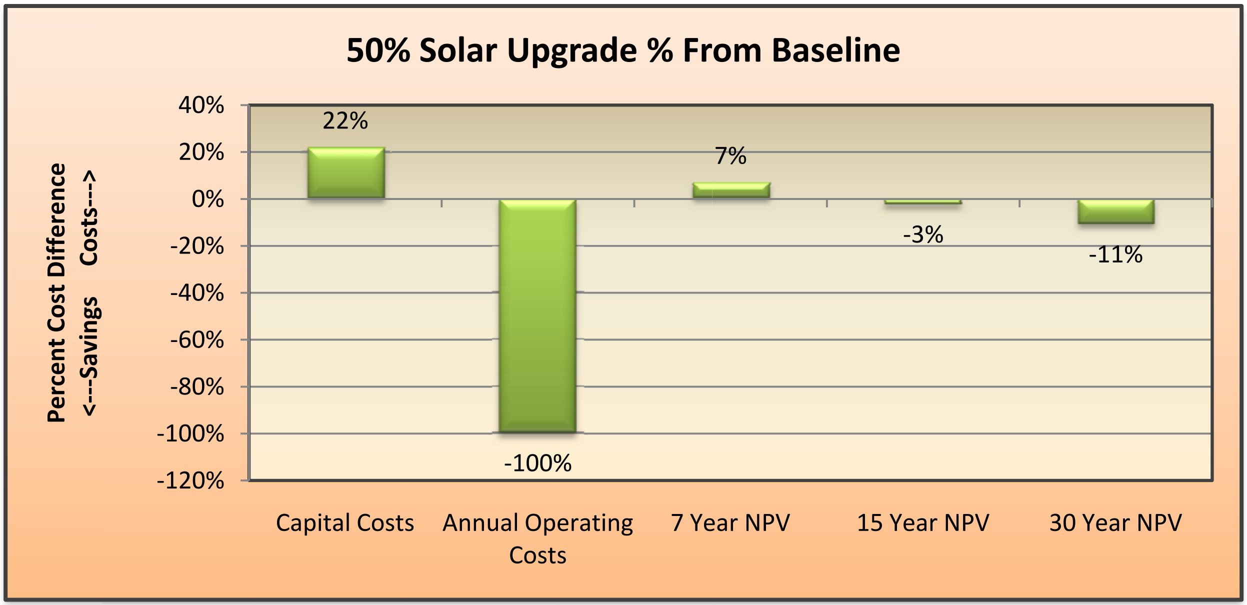
Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	3%	3%	3%
15 Year NPV	-1%	-1%	-1%
30 Year NPV	-6%	-6%	-6%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

Figure 24: Life Cycle Cost Analysis for 50% Solar Upgrade



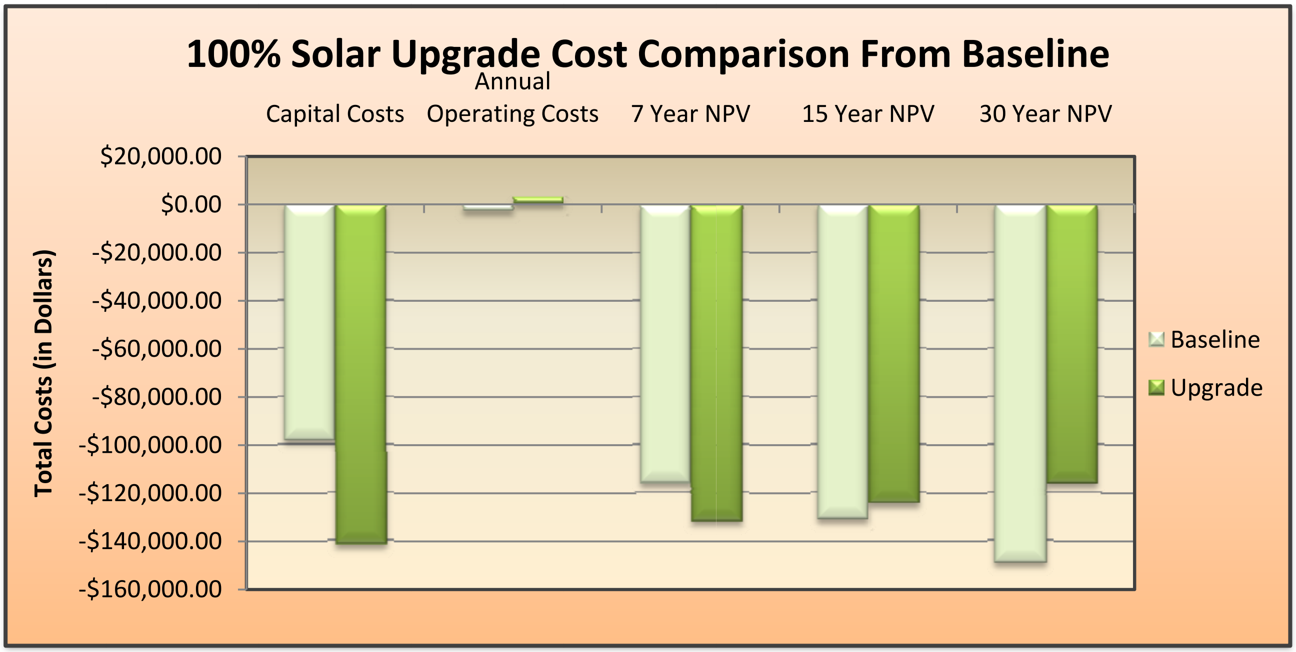


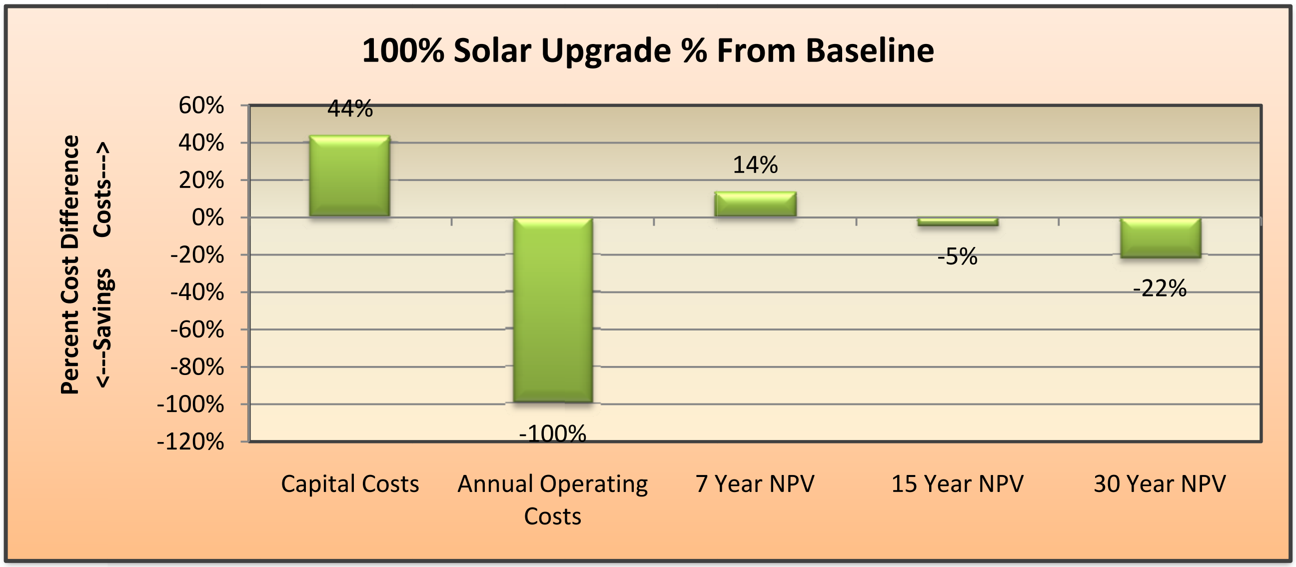
Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	7%	7%	7%
15 Year NPV	-3%	-3%	-3%
30 Year NPV	-11%	-11%	-11%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

Figure 25: Life Cycle Cost Analysis for 100% Solar Upgrade





Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	14%	14%	14%
15 Year NPV	-5%	-5%	-5%
30 Year NPV	-22%	-22%	-22%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

Figure 26: Cost Comparison of Solar Upgrades with Baseline Model

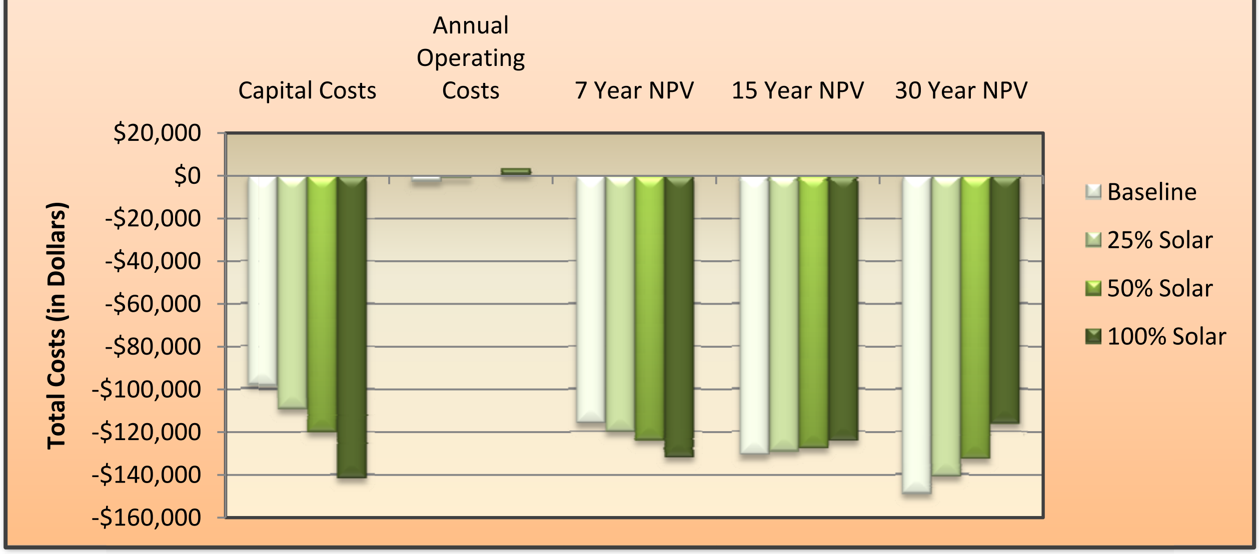
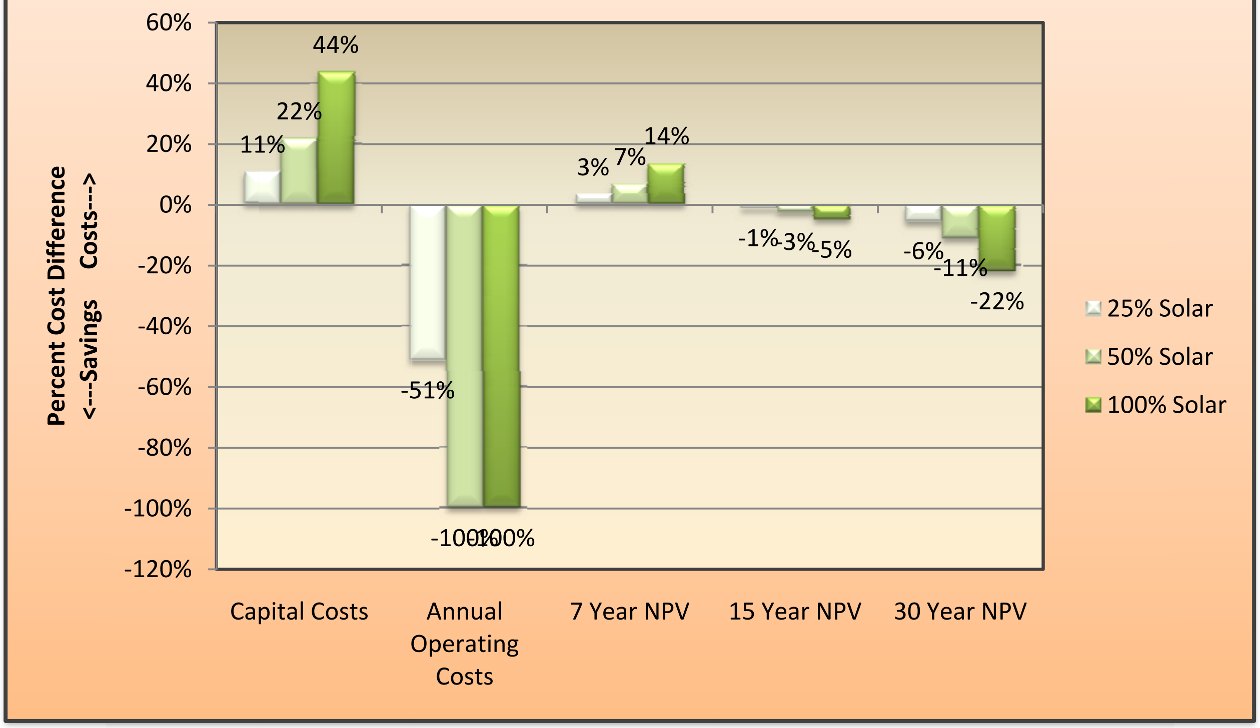


Figure 27: Percent Divergence of Solar Upgrades from Baseline Model



4.4 ENERGY STAR and LEED for Homes Scenarios

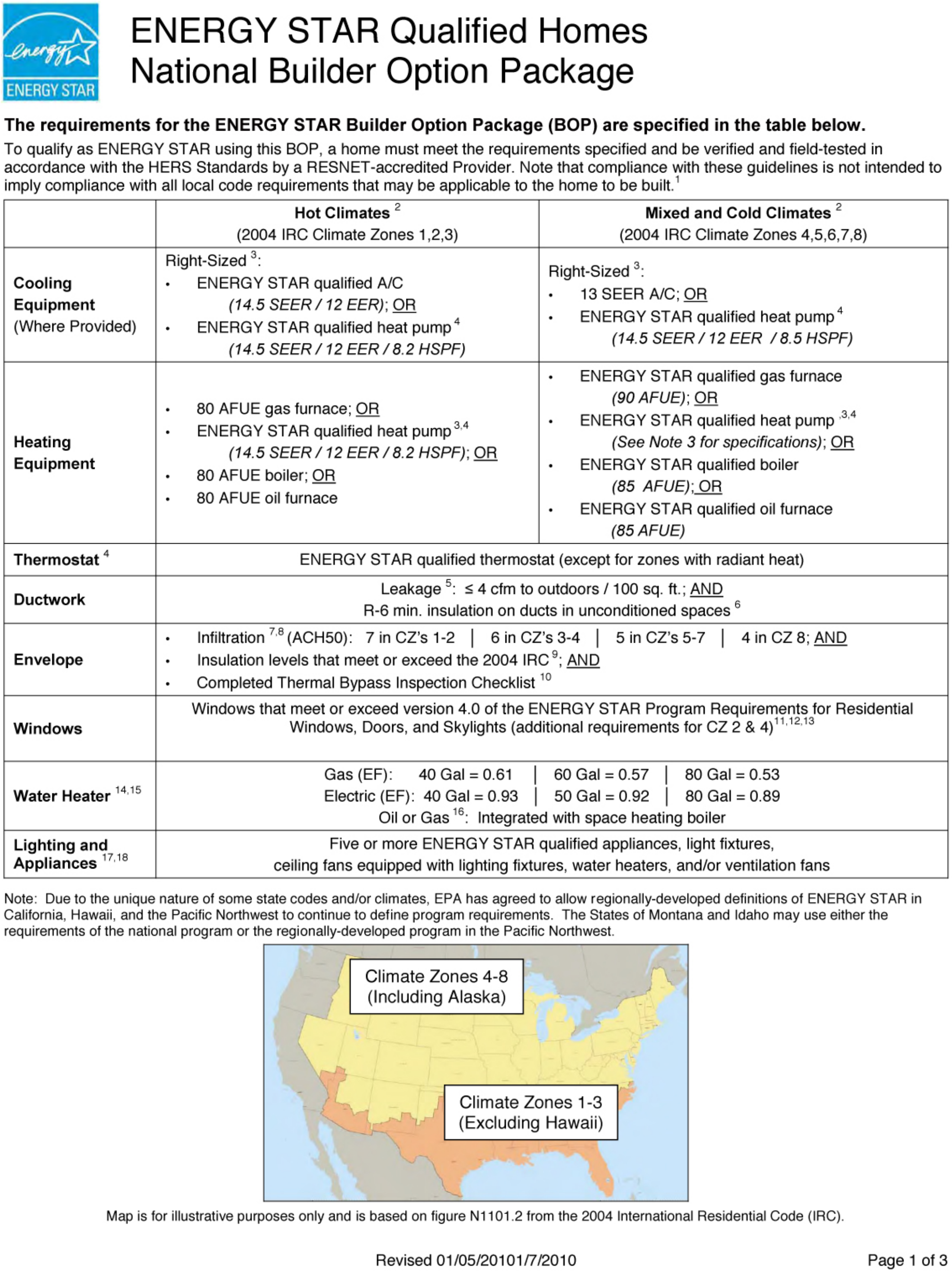
In our next modeled series, we present three ENERGY STAR scenarios, which double as LEED for Homes scenarios as the latter are tied to ENERGY STAR for energy performance. The three scenarios are: Basic, Enhanced, and Advanced. The ENERGY STAR 2.5 standard, which is a transitional standard keyed to IECC 2006, is used to produce these scenarios. Note that ENERGY STAR 2.5 is scheduled to be replaced by ENERGY STAR 3.0 in April 2011. Within the 2.5 standard, a home must perform at least 15% better than IECC 2006, making it roughly equivalent to the IECC 2009 energy standard.

The Basic ENERGY STAR scenario beats IECC 2009 by a little more than 15%, making it approximately 30% more efficient than IECC 2006. This would be equivalent to a HERS rating of 85 once ENERGY STAR recalibrates based on the 2009 code, or a HERS rating of 70 based on IECC 2006, although REM/Design does not produce a HERS rating. The Basic ENERGY STAR scenario relies chiefly on envelope strategies for achieving energy efficiency.

The Enhanced ENERGY STAR scenario adds more efficient mechanical systems to the mix along with a substantial investment in rooftop solar panels. This reduces its net energy consumption by 33% relative to IECC 2009, and 48% relative to IECC 2006. This would be equivalent to a HERS rating of 52 under IECC 2006 and a HERS rating of 67 under IECC 2009

The Advanced ENERGY STAR scenario relies instead on a ground-source heat pump for heating and cooling. This reduces its net energy consumption by 62% relative to IECC 2009, and about 77% relative to IECC 2006. This would be equivalent to a HERS rating of 23 under IECC 2006 and a HERS rating of 48 under IECC 2009.

The ENERGY STAR Builder Option Package provides several kinds of options for meeting ENERGY STAR performance requirements. The modeling for ENERGY STAR Homes was based on configurations from the 2009 baseline model. It uses a 13 SEER A/C for cooling equipment and a 90 AFUE gas furnace for heating equipment. The ENERGY STAR document provides an equation to calculate the certified energy factor (EF) for water heaters: Gas DHW EF$\geqq$0.69-(0.002x Tank Gallon Capacity). Thus, the baseline model had a 35 gallon gas water heater, which the EF should be larger than 0.62 in the ENERGY STAR model.



ENERGY STAR Qualified Homes National Builder Option Package

The requirements for the ENERGY STAR Builder Option Package (BOP) are specified in the table below.

To qualify as ENERGY STAR using this BOP, a home must meet the requirements specified and be verified and field-tested in accordance with the HERS Standards by a RESNET-accredited Provider. Note that compliance with these guidelines is not intended to imply compliance with all local code requirements that may be applicable to the home to be built.[1]

	Hot Climates [2] (2004 IRC Climate Zones 1,2,3)	**Mixed and Cold Climates** [2] (2004 IRC Climate Zones 4,5,6,7,8)
Cooling Equipment (Where Provided)	Right-Sized [3]: • ENERGY STAR qualified A/C *(14.5 SEER / 12 EER)*; OR • ENERGY STAR qualified heat pump [4] *(14.5 SEER / 12 EER / 8.2 HSPF)*	Right-Sized [3]: • 13 SEER A/C; OR • ENERGY STAR qualified heat pump [4] *(14.5 SEER / 12 EER / 8.5 HSPF)*
Heating Equipment	• 80 AFUE gas furnace; OR • ENERGY STAR qualified heat pump [3,4] *(14.5 SEER / 12 EER / 8.2 HSPF)*; OR • 80 AFUE boiler; OR • 80 AFUE oil furnace	• ENERGY STAR qualified gas furnace *(90 AFUE)*; OR • ENERGY STAR qualified heat pump [,3,4] *(See Note 3 for specifications)*; OR • ENERGY STAR qualified boiler *(85 AFUE)*; OR • ENERGY STAR qualified oil furnace *(85 AFUE)*
Thermostat [4]	ENERGY STAR qualified thermostat (except for zones with radiant heat)	
Ductwork	Leakage [5]: ≤ 4 cfm to outdoors / 100 sq. ft.; AND R-6 min. insulation on ducts in unconditioned spaces [6]	
Envelope	• Infiltration [7,8] (ACH50): 7 in CZ's 1-2 | 6 in CZ's 3-4 | 5 in CZ's 5-7 | 4 in CZ 8; AND • Insulation levels that meet or exceed the 2004 IRC [9]; AND • Completed Thermal Bypass Inspection Checklist [10]	
Windows	Windows that meet or exceed version 4.0 of the ENERGY STAR Program Requirements for Residential Windows, Doors, and Skylights (additional requirements for CZ 2 & 4)[11,12,13]	
Water Heater [14,15]	Gas (EF): 40 Gal = 0.61 | 60 Gal = 0.57 | 80 Gal = 0.53 Electric (EF): 40 Gal = 0.93 | 50 Gal = 0.92 | 80 Gal = 0.89 Oil or Gas [16]: Integrated with space heating boiler	
Lighting and Appliances [17,18]	Five or more ENERGY STAR qualified appliances, light fixtures, ceiling fans equipped with lighting fixtures, water heaters, and/or ventilation fans	

Note: Due to the unique nature of some state codes and/or climates, EPA has agreed to allow regionally-developed definitions of ENERGY STAR in California, Hawaii, and the Pacific Northwest to continue to define program requirements. The States of Montana and Idaho may use either the requirements of the national program or the regionally-developed program in the Pacific Northwest.

Map is for illustrative purposes only and is based on figure N1101.2 from the 2004 International Residential Code (IRC).

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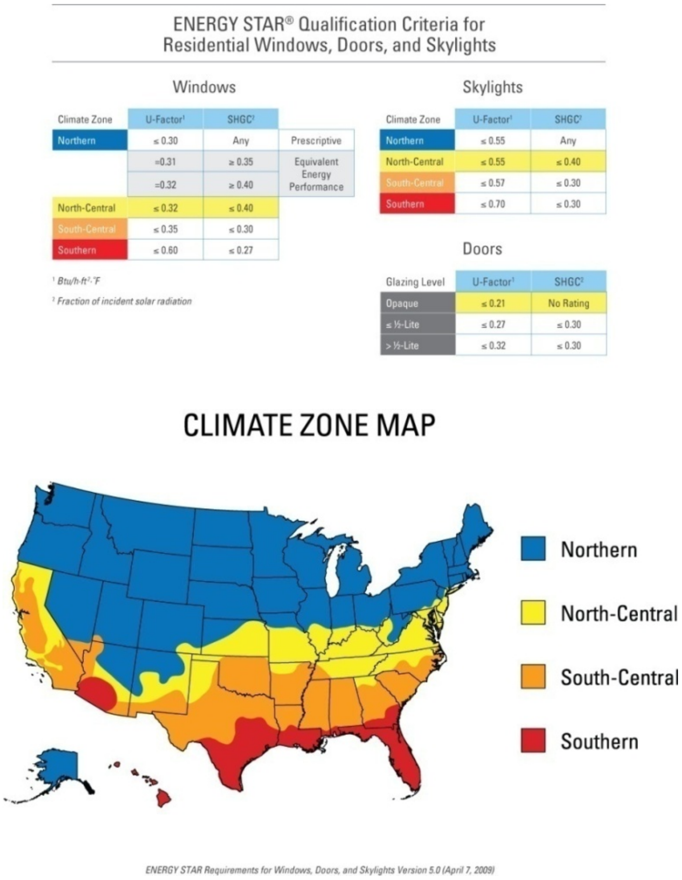
Figure 28. Source: ENERGY STAR

For the windows, doors and skylights, ENERGY STAR provides other qualification criteria. However, there was no skylight set up in the baseline model. Therefore, it is not modeled in these scenarios. According to ENERGY STAR, New Jersey is considered a North-Central area that follows the yellow category in the following figure.



ENERGY STAR® Qualification Criteria for Residential Windows, Doors, and Skylights

Windows

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.30	Any	Prescriptive
	=0.31	≥ 0.35	Equivalent Energy Performance
	=0.32	≥ 0.40	
North-Central	≤ 0.32	≤ 0.40	
South-Central	≤ 0.35	≤ 0.30	
Southern	≤ 0.60	≤ 0.27	

[1] Btu/h·ft²·°F

[2] Fraction of incident solar radiation

Skylights

Climate Zone	U-Factor[1]	SHGC[2]
Northern	≤ 0.55	Any
North-Central	≤ 0.55	≤ 0.40
South-Central	≤ 0.57	≤ 0.30
Southern	≤ 0.70	≤ 0.30

Doors

Glazing Level	U-Factor[1]	SHGC[2]
Opaque	≤ 0.21	No Rating
≤ ½-Lite	≤ 0.27	≤ 0.30
> ½-Lite	≤ 0.32	≤ 0.30

CLIMATE ZONE MAP

ENERGY STAR Requirements for Windows, Doors, and Skylights Version 5.0 (April 7, 2009)

Figure 29. Source: ENERGY STAR

4.4.1 LEED

Leadership in Energy and Environmental Design (LEED) for Homes is a program developed by the U.S. Green Building Council that provides homebuilders with a standardized framework for using sustainable practices through a point-based system. The overall performance of a home is divided into eight categories: Innovation & Design Process; Location & Linkages; Sustainable Sites; Water Efficiency; Awareness & Education; Materials & Resources; Indoor Environmental Quality; and more specific to this analysis, Energy & Atmosphere (E&A). Based on the total number of points a home obtains, it may achieve one of four levels of certification: LEED Certified, Silver, Gold or Platinum.[46]

There are a total of 136 points available on the LEED point checklist. Only 38 of the 136 points are based on a home's E&A efficiency. In order to obtain certification, a home must meet the prerequisites of all other sections, and receive sufficient points in those sections to reach various certification levels as shown below. As such an adjusted score must be calculated using a proxy that takes into account the other potential points from their respective categories. In order to obtain a proxy measurement for the various levels of LEED certification, the proportions of the 136 total available points needed to obtain certification along with the 38 available points within the E&A category were calculated.[47] The points listed below are the total and minimum proxy points needed for certification rounded to the nearest integer.

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[46] LEED-H Manual

[47] The ratio of total EA points to total project points can be represented as: 38/136 = 0.279

Table 2. LEED Point Breakdown

Certification Level	Total Points Needed	Percentage of Total	Proxy Points Needed
Certified	45-59	33%	13
Silver	60-74	44%	17
Gold	75-89	55%	21
Platinum	90-139	66%	25

It is worth noting that a home can still achieve certification with fewer points in E&A than those listed above by getting a higher proportion of the total points in other sections, so long as all prerequisites are met. Doing so may be common practice because some points are substantially cheaper than using costly energy-efficient. It also important to mention that the E&A category has two possible mutually-exclusive pathways. The first is performance-based, where 34 of the 38 points may be awarded based on the home's energy performance, regardless of the materials used. The second pathway is prescriptive, with points being awarded for meeting certain design standards in the following categories: Insulation, Air Infiltration, Windows, Duct Tightness, Space Heating & Cooling, Water Heating, Lighting, Appliances, and Renewable Energy.[48] This analysis simulates both of these paths for a more comprehensive analysis.

As noted earlier, LEED-H Energy and Atmosphere points are tied to ENERGY STAR performance. The Basic ENERGY STAR scenario (envelope improvements) is equivalent to LEED Silver, the Enhanced ENERGY STAR scenario (add HVAC improvements and solar panels) is equivalent to LEED Gold, and the Advanced ENERGY STAR scenario (featuring ground source heat pumps) is equivalent to LEED Platinum. Thus, we do not develop separate energy modeling for LEED, using instead the ENERGY STAR results to inform the LEED scenarios..

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[48] LEED-H Manual, 54

The Energy Star Basic upgrade incurs construction costs that are about $4k higher than the baseline building, but it reduces operating costs by over $500 per year, achieving simple payback within 25 years. Only the 30 year NPV is superior to that of the baseline building.

The ENERGY STAR Enhanced upgrade, featuring a solar array, has a construction cost that is about $22k higher than the baseline case, but it reduces annual operating costs to zero—and then some—by delivering annual **revenues** of over $900. The scenario achieves simple payback within 8 years and the 15 and 30 year NPVs beat the baseline case.

The Energy Star Advanced upgrade, which uses a ground-source heat pump, has a construction cost that is about $ 18k higher than the baseline building.[49] Annual operating costs drop by about $400, or 13%, much smaller than the energy savings of 62%, because the energy mix shifts away from (cheap) natural gas to (more expensive) electricity. This scenario does not achieve simple payback until 62 years pass, and its NPV is worse than that of the baseline case at 7, 15, and 30 years, making it an unattractive investment. Even a scenario with high future energy prices does not change this outcome. Only a low-cost installation will make this an attractive investment.

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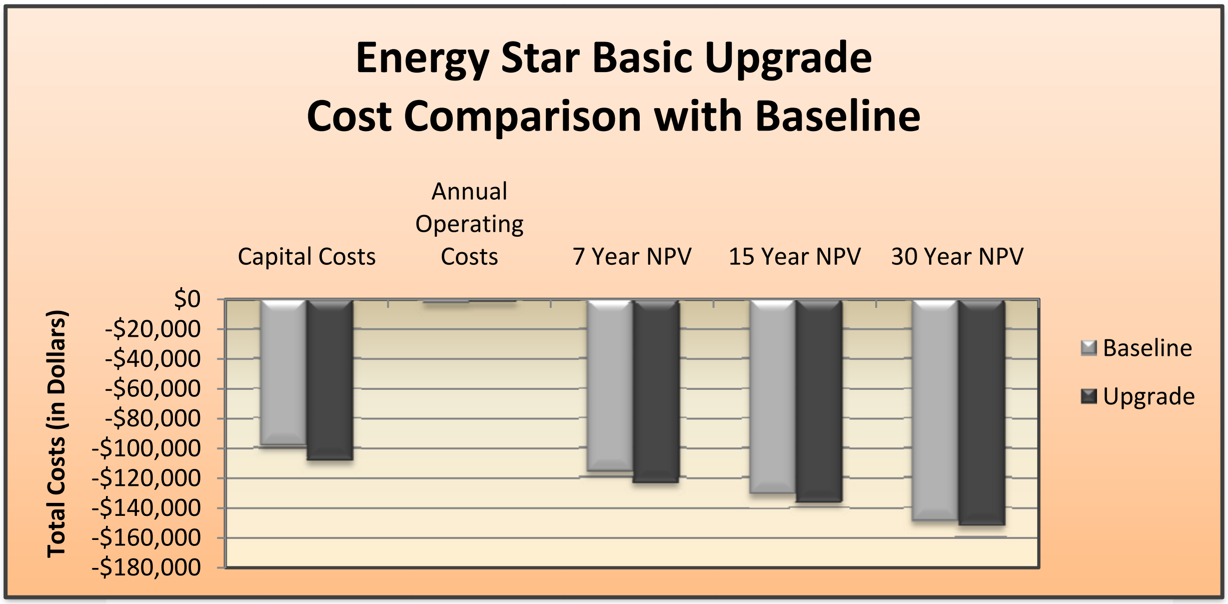
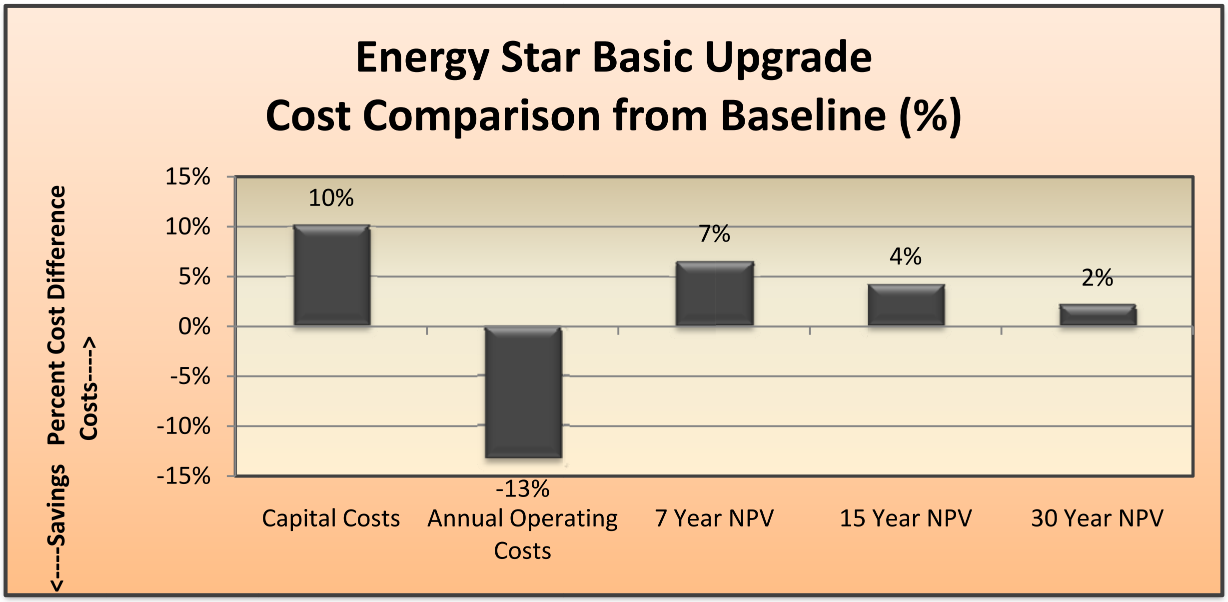
[49] As discussed in the section on mechanical system upgrades, the cost reported here is for a vertical borehole system. A horizontal piping loop system would cost substantially less, likely achieving simple payback in less than 10 years.

Figure 30: Life Cycle Cost Analysis for ENERGY STAR Basic Upgrade



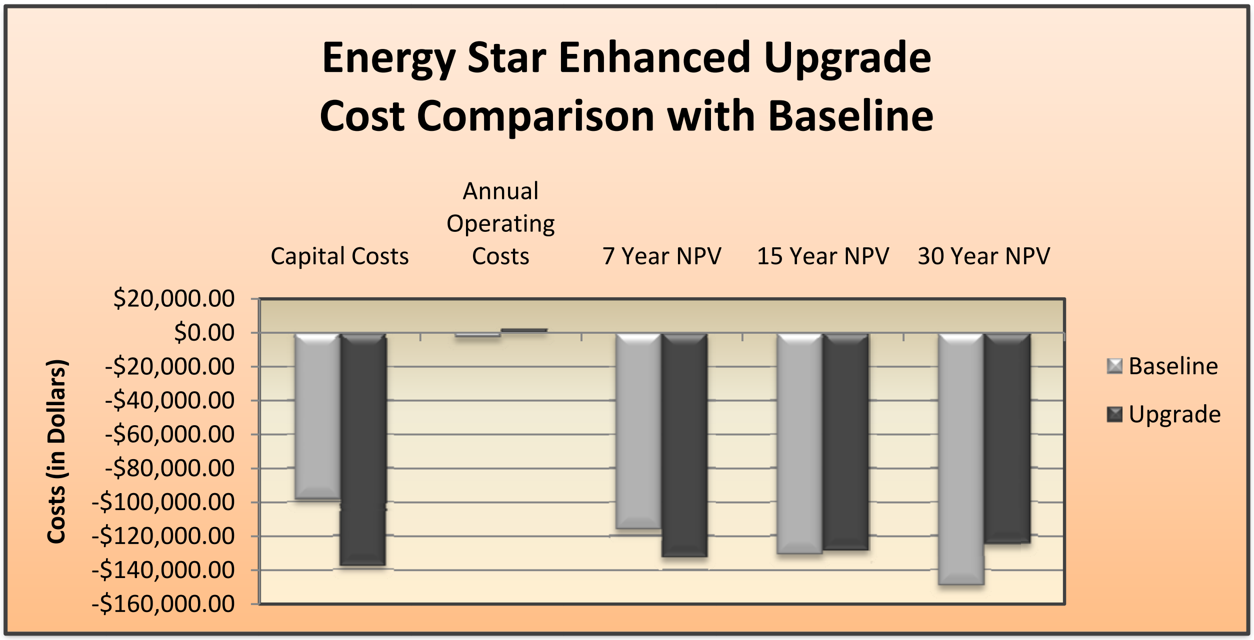


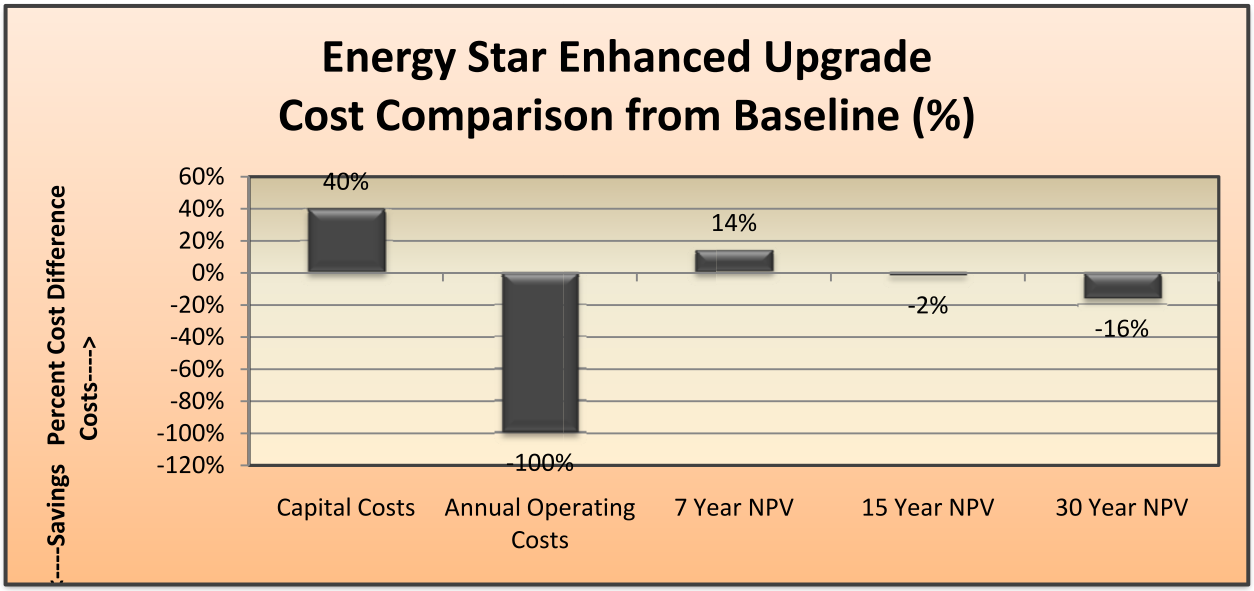
Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	7%	7%	6%
15 Year NPV	5%	4%	4%
30 Year NPV	3%	2%	1%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

Figure 31: Life Cycle Cost Analysis for ENERGY STAR Enhanced Upgrade



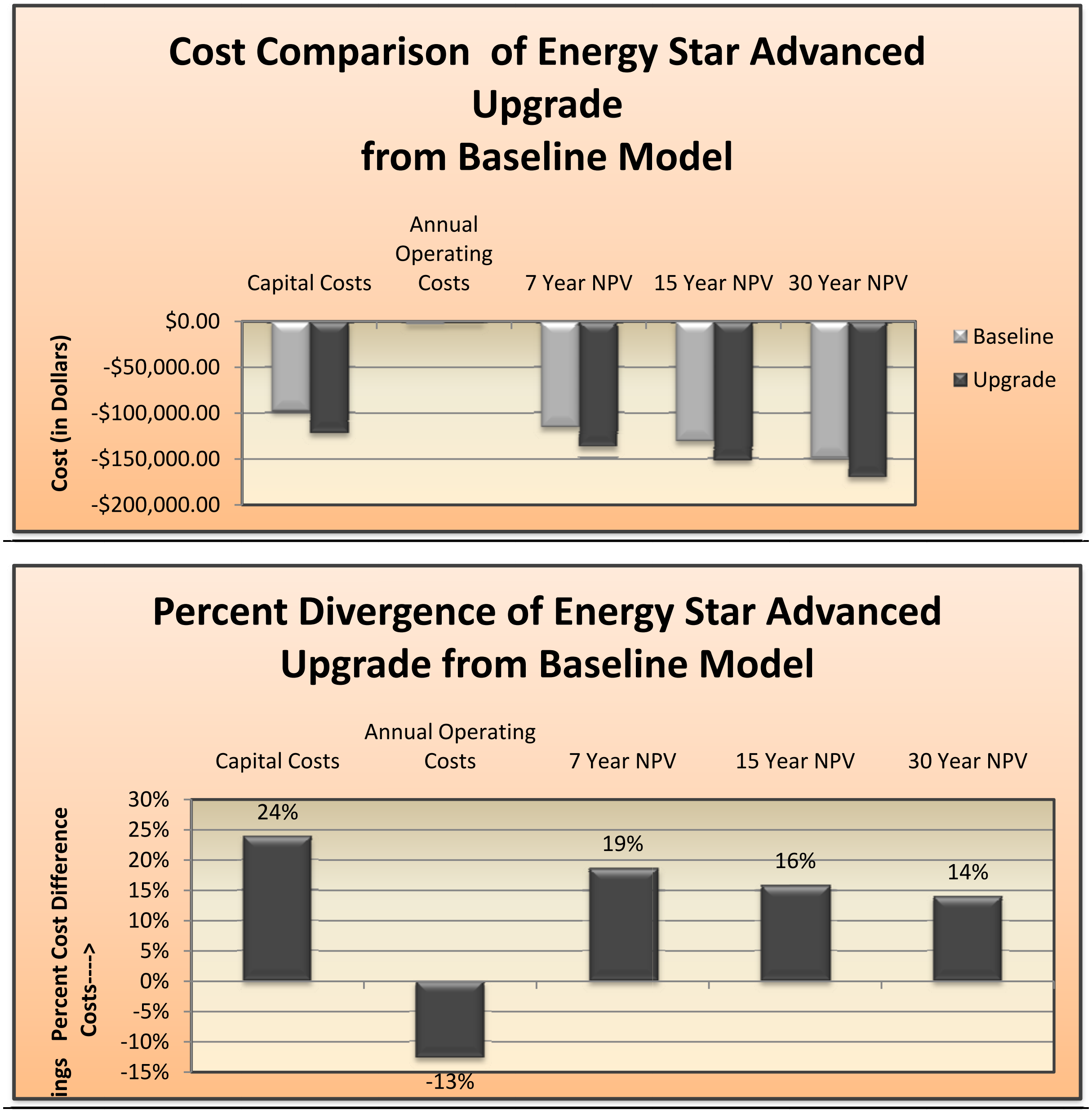


Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	14%	14%	14%
15 Year NPV	-2%	-2%	-2%
30 Year NPV	-16%	-16%	-18%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

Figure 32: Life Cycle Cost Analysis for ENERGY STAR Advanced Upgrade



Sensitivity of Difference in NPV to Energy Prices & Time Horizons

Annual Energy Price Growth Rate	0%	1.5%	3%
7 Year NPV	13%	13%	12%
15 Year NPV	10%	11%	9%
30 Year NPV	7%	9%	6%

Note that negative values mean that the scenario is less costly on a NPV basis than the baseline design. Positive values mean that the scenario costs more than the baseline design.

Figure 33: Cost Comparison of Energy Star Upgrades with Baseline Model

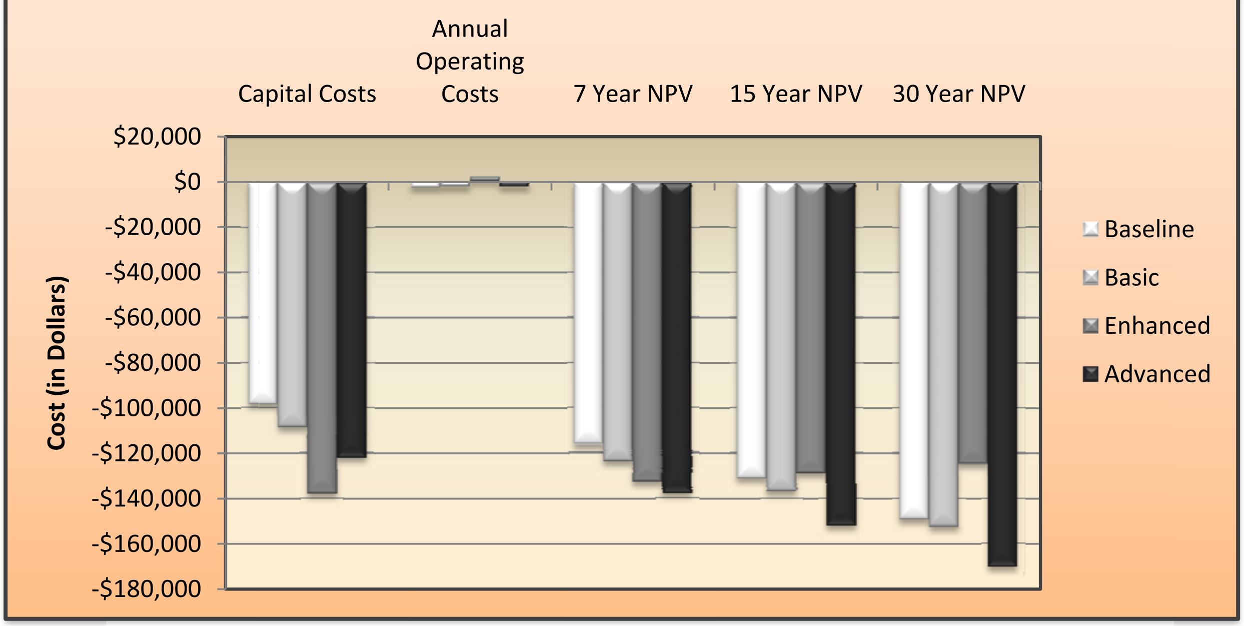
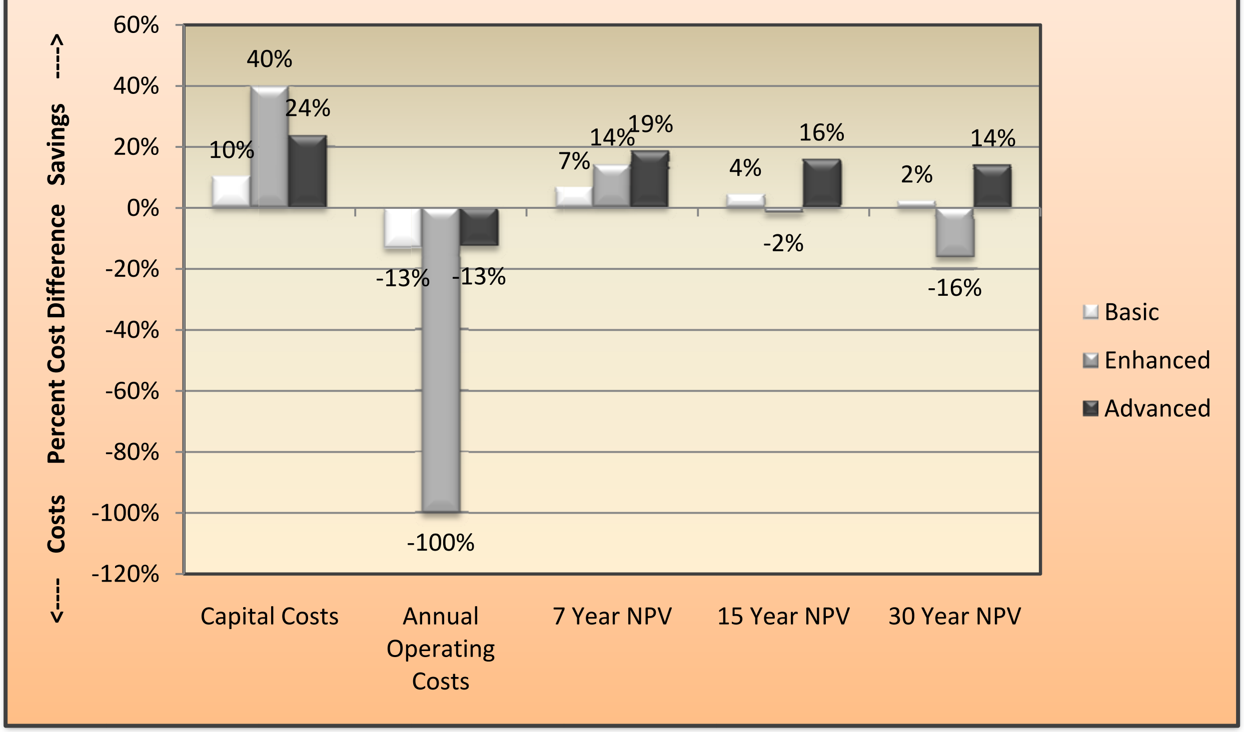


Figure 34: Percent Divergence of Energy Star Upgrades from Baseline Model



4.4.2 ENERGY STAR/LEED VALUATION

An additional analysis of the ENERGY STAR/LEED for Homes scenarios is afforded by a partial application of the Green Building Underwriting Standard. Figure 36, below, shows the estimated Green Building Underwriting Standard Score for each of the ENERGY STAR/LEED scenarios and what percent of the total available points each scenario achieves. As with the scenarios themselves, only energy and energy efficiency attributes are addressed. The Enhanced and Advanced Bundles (28 pts. and 24 pts. respectively) both score higher than the Basic Bundle (16 pts.), but the Enhanced Package earns a greater percentage of the maximum allowable points (79%) because it garners points for having on-site renewable energy. This analysis demonstrates that the absence of just one of the Underwriting Standard criteria can have a detrimental effect on the overall score and potentially, the perceived value of the property being appraised.

Figure 35: Green Building Underwriting Standard Scorecard for the ENERGY STAR Scenarios

Calculation Methodology - Green Building Underwriting Standard

Scenario 1 - ENERGY STAR Basic

Sorted by LEED criteria/building attribute	**LEED Point**		**Value Range**		**SCORE**	**Adjustment Factor**	**TOTAL**
	YES	**NO**	**Low**	**High**			
Energy Efficiency	x		1	5	3	3	9
On-Site Renewable Energy		x	1	3	0	3	0
Orientation for Solar	x		1	3	2	2	4
Energy Reduction: Hot Water & Appliances	x		1	3	2	1.7	3.4
TOTAL POINTS							**16.4**
% of Maximum Allowable				**36 points maximum**			**45.56%**

Calculation Methodology - Green Building Underwriting Standard

Scenario 2 - ENERGY STAR Enhanced (w/Solar)

Sorted by LEED criteria / building attribute	**LEED Point**		**Value Range**		**SCORE**	**Adjustment Factor**	**TOTAL**
	YES	**NO**	**Low**	**High**			
Energy Efficiency	x		1	5	5	3	15
On-Site Renewable Energy	x		1	3	2	3	6
Orientation for Solar	x		1	3	2	2	4
Energy Reduction: Hot Water & Appliances	x		1	3	2	1.7	3.4
TOTAL POINTS							**28.4**
% of Maximum Allowable				**36 points maximum**			**78.89%**

Calculation Methodology - Green Building Underwriting Standard

Scenario 3 - ENERGY STAR Advanced (w/Geothermal)

Sorted by LEED criteria / building attribute	LEED Point		Value Range		SCORE	Adjustment Factor	TOTAL
	YES	NO	Low	High			
Energy Efficiency	x		1	5	5	3	15
On-Site Renewable Energy		x	1	3	0	3	0
Orientation for Solar	x		1	3	2	2	4
Energy Reduction: Hot Water & Appliances	x		1	3	3	1.7	5.1
TOTAL POINTS							**24.1**
% of Maximum Allowable			**36 points maximum**				**66.94%**

The ENERGY STAR Yardstick Score/Converted HERS Rating section is a pivotal portion of the Green Value Score and accounts for the largest portion of the Value Ratio (40%). Figure 37 illustrates how each scenario would be scored based on their estimated HERS Ratings equivalency under both ENERGY STAR Version 2.5, and ENERGY STAR version 3. It is important to note that these are not actual HERS Ratings, but the estimated numbers that the scenarios would receive based on their energy efficiency.[50]

Each scenario scores 70 or above based on IECC 2006 standards. The advanced bundle exceeds the minimum score needed to score 100 points (a HERS rating of 39) though in practice, this would be a difficult goal to achieve. As standards are raised under IECC 2009, the amount of points that each scenario earns is decreased by 5-10%.

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[50] Current literature suggest that the HERS rating is 15% more efficient than 2006 IECC standards and that 2009 standards are 13-14% better than 2006. The numbers have been consistently rounded up for simplicity and may slightly overstate actual performance.

Figure 36: Converted HERS Rating for the ENERGY STAR Scenarios

CMP GREEN VALUE SCORE MATRIX: HERS CONVERTED RATING			
IECC 2006 Energy Standard			
	HERS Rating	Converted Score	% of Maximum Allowable
Scenario 1 - ENERGY STAR Basic Bundle	70	70	70%
Scenario 2 - ENERGY STAR Enhanced Bundle	55	80	80%
Scenario 3 - ENERGY STAR Advanced Bundle	25	100	100%

CMP GREEN VALUE SCORE MATRIX: HERS CONVERTED RATING			
IECC 2009 Energy Standard			
	HERS Rating	Converted Score	% of Maximum Allowable
Scenario 1 - ENERGY STAR Basic Bundle	85	60	60%
Scenario 2 - ENERGY STAR Enhanced Bundle	70	70	70%
Scenario 3 - ENERGY STAR Advanced Bundle	40	95	95%

The application of the Underwriting Standard to the ENERGY STAR/LEED scenarios suggests both its strengths and weaknesses. On the one hand, it is easy to use and gives potentially useful information to complement standard underwriting criteria. In this case, the scoring results reinforce our LCC findings; higher scoring scenarios are also those which are more cost-effective. On the other hand, the Underwriting Standard allows for a great deal of subjectivity in how scoring is assigned and it may overweight certain categories to the extent that an otherwise superior property is punished for the lack of an attribute which may not be cost-effective to implement. Clearly, much more study and evaluation of the Underwriting Standard is called for; this partial application is a small start. Tempting would be a larger study that continues the theme of comparing LCC results with added property value as estimated by the Underwriting Standard and those that employ it.

5 Conclusions and Policy Implications

This report concludes with an ordered comparison of all of the scenarios, from most to least cost-effective according to several measures. The first comparison orders scenarios by net energy savings relative to the baseline building. The next comparison is by years to simple payback, that is, by the difference in construction costs divided by the difference in annual operating costs between the baseline case and each scenario. The third, fourth, and fifth comparisons order scenarios by the net present value of total costs at time horizons of 7, 15, and 30 years, respectively. Scenarios to the left of the baseline case in the graph are more cost-effective than the baseline building, and those to the right are less cost-effective.

5.1 Ordered Comparisons

Ordered comparisons across scenarios reveal which green options are cost-effective relative to current building practices. This section shows scenarios ordered by net energy consumption, simple payback, as well as NPV of total costs after 7 years, 15 years, and 30 years.

5.2 Net Energy Consumption

Figure 39 compares the net annual energy savings relative to the baseline case for the range of green options studied. Envelope strategies achieve savings in the 10% – 30% range. Greater savings require integrated packages of envelope improvements, mechanical system improvements, and solar panels on the roof. The greatest energy savings achieved in these analyses is 62% by means of an integrated ENERGY STAR bundle that combines an efficient envelope and innovative mechanical system.

5.3 Simple Payback Period Comparison

As mentioned earlier in the report, the simple payback period is an important metric that considers initial investment costs and the resulting annual cash flow to determine the amount of time it takes for an investment to pay for itself. As seen in Figures 38 and 40, there is a range of simple payback periods for the various energy efficiency upgrades modeled in this report. Six of the upgrades have a payback period within the time of the average home tenure (7 years), 11 pay back within the time of an average short-term mortgage (15 years), 12 pay back within the term of a standard long-term mortgage (30 years), and two of the upgrades do not pay back even within the term of a standard 30-year mortgage.

Both the basic and enhanced framing and insulation envelope upgrades have negative payback periods because their upfront capital costs are lower than those of the baseline. The basic envelope upgrade not only pays for itself at the time of construction, but it provides substantial initial savings. The ENERGY STAR Enhanced upgrade pays for itself within 8 years.

Figure 37: Simple Payback Period Comparison (in Years)

Envelope Upgrades	
Basic Framing/Insulation	0
Enhanced Framing/Insulation	0
Door/Window	14
Enhanced Framing/Insulation with Door/Window Upgrade	4
Active Mechanical Upgrades	
Low Output Active Mechanical Upgrade	9
Mid Output Active Mechanical Upgrade	15
High Output Active Mechanical Upgrade	32
Solar Upgrades	

Basic Solar	7
Enhanced Solar	7
Advanced Solar	7
ENERGY STAR Upgrades	
ENERGY STAR Basic	25
ENERGY STAR Enhanced	8
ENERGY STAR Advanced (w/ Geothermal)	62

5.4 Net Present Value Comparisons

Given that the simple payback period does not calculate the time value of money or the savings that may continue from a project after the sum of the original investment is paid back, it is important for investors to also look at Net Present Value (NPV) when determining a project's economic viability. Figures 41, 42, and 43 show the 7, 15, and 30-year NPV calculations for each green upgrade modeled in this report.

The results show that the most cost-effective energy efficient green technologies over a 7-year time period are efficiency improvements in the building envelope. As discussed earlier, much of this benefit comes from the use of advanced framing techniques.

As seen in Figure 42, the low level active mechanical system upgrade becomes cost-effective over a 15 year time period. Active solar PV systems also become cost-effective investments when looking at this time frame. The enhanced ENERGY STAR design also becomes attractive.

A Net-zero solar PV system becomes the most cost-effective green investment over a 30-year time period, followed by the enhanced ENERGY STAR bundle that also includes some solar. The upgrades using a geothermal heating system are the two least cost-effective options over the short- and long-term.

5.5 Cost-effectiveness in Context

During the past decade, as the building industry has focused on improving energy efficiency, its energy codes have become more stringent. The updated New Jersey energy code based on IECC 2009 that is now in effect represents a significant advance over its 3-year old predecessor. Many of the obvious energy-efficiency options are now incorporated, so that good insulation, efficient lighting, and high-performing appliances represent standard practices rather than cutting-edge innovations.

This analysis demonstrates that low-hanging fruit remain, however. Figure 39 shows that there are a wide variety of options for reducing household energy consumption by another 20% – 30% or more. Figures 40 – 43 confirm that most of these options make economic sense within the context of residential mortgage financing and typical homeowners' time horizons.

The figures also show that some interesting innovations are not cost-effective in a conventional sense. Homeowners investing in high-performance windows and ground-source heat pumps may have other motivations, such as a desire for enhanced comfort, reduced environmental impacts, better views, or energy self-sufficiency. Investments made with such motivations may not recoup their full value at resale.

There have not yet been enough resales of green, energy-efficient homes to establish their value in the marketplace. Hence, the cost-based approach presented in this analysis provides a first indication of which energy efficiency investments are likely to hold their value as the residential property market re-ignites. It is clear that a variety of envelope and equipment improvements are cost-effective, especially when assembled into synergistic packages that allow downsizing of equipment. Solar systems remain attractive for well-capitalized homeowners, although their cost-effectiveness is highly dependent on future SREC values. Energy Star labels and LEED certifications do not intrinsically connote cost-effectiveness, but they may help homebuyers identify properties that incorporate synergistic packages of energy-efficient options.

The CMP Green Value Score Rating System offers guidance for translating ENERGY STAR and LEED points into increments of residential property value, as we show in this report. This tool shows promise for guiding value assessments of green buildings, however, users still encounter much subjectiveness and ambiguity, meaning that it remains primarily a tool for expert use.

Future research should examine the adaptability of buildings for easy energy-efficiency retrofits, regional differentials in the relative attractiveness of specific energy-efficient alternatives, and the site- and landscape-related factors that influence energy performance of homes. It would also be valuable to identify "green" data fields to add to the Multiple Listing Service database of real property for sale to make green features more transparent to homebuyers and to allow analysis of their value at resale.

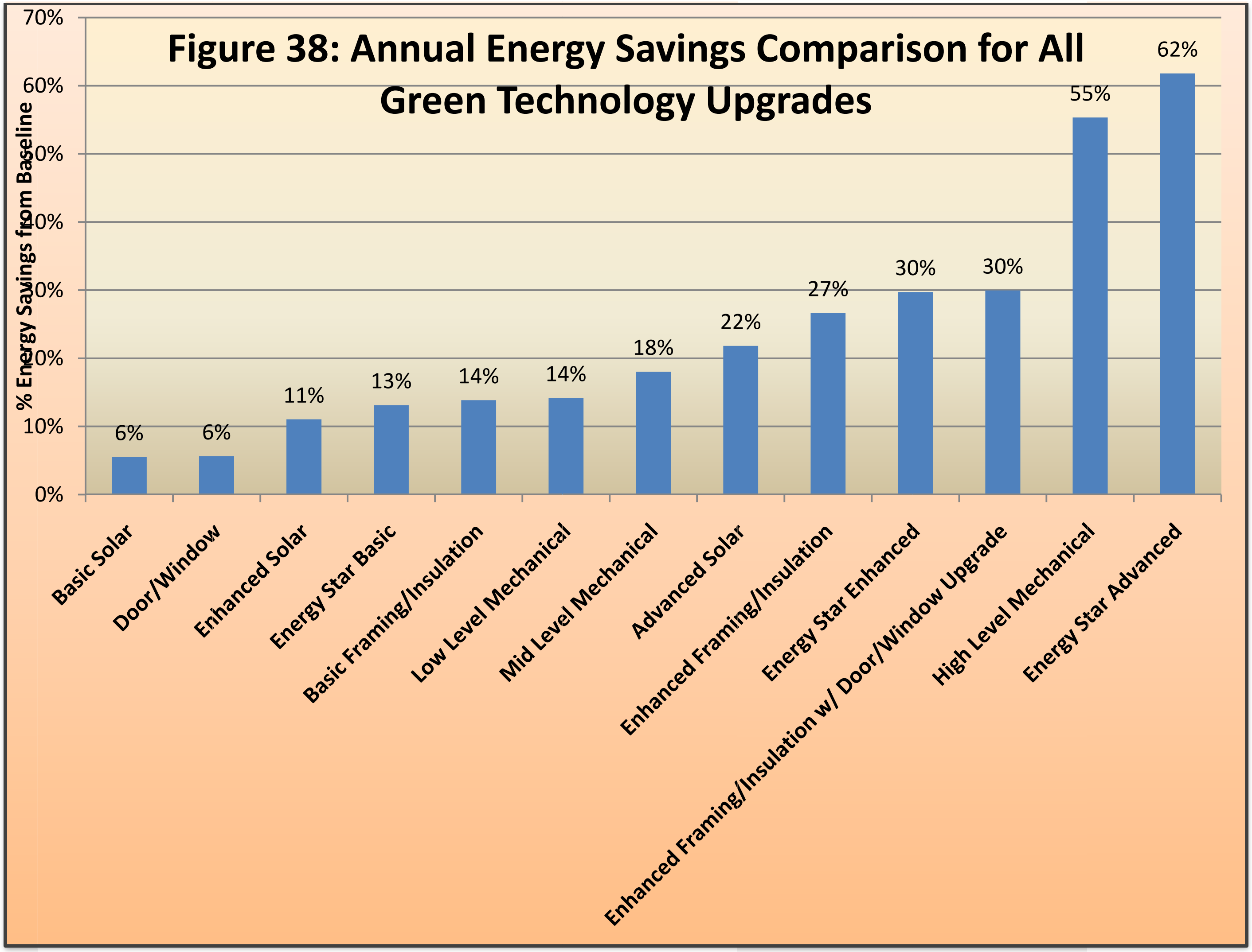


Figure 38: Annual Energy Savings Comparison for All Green Technology Upgrades

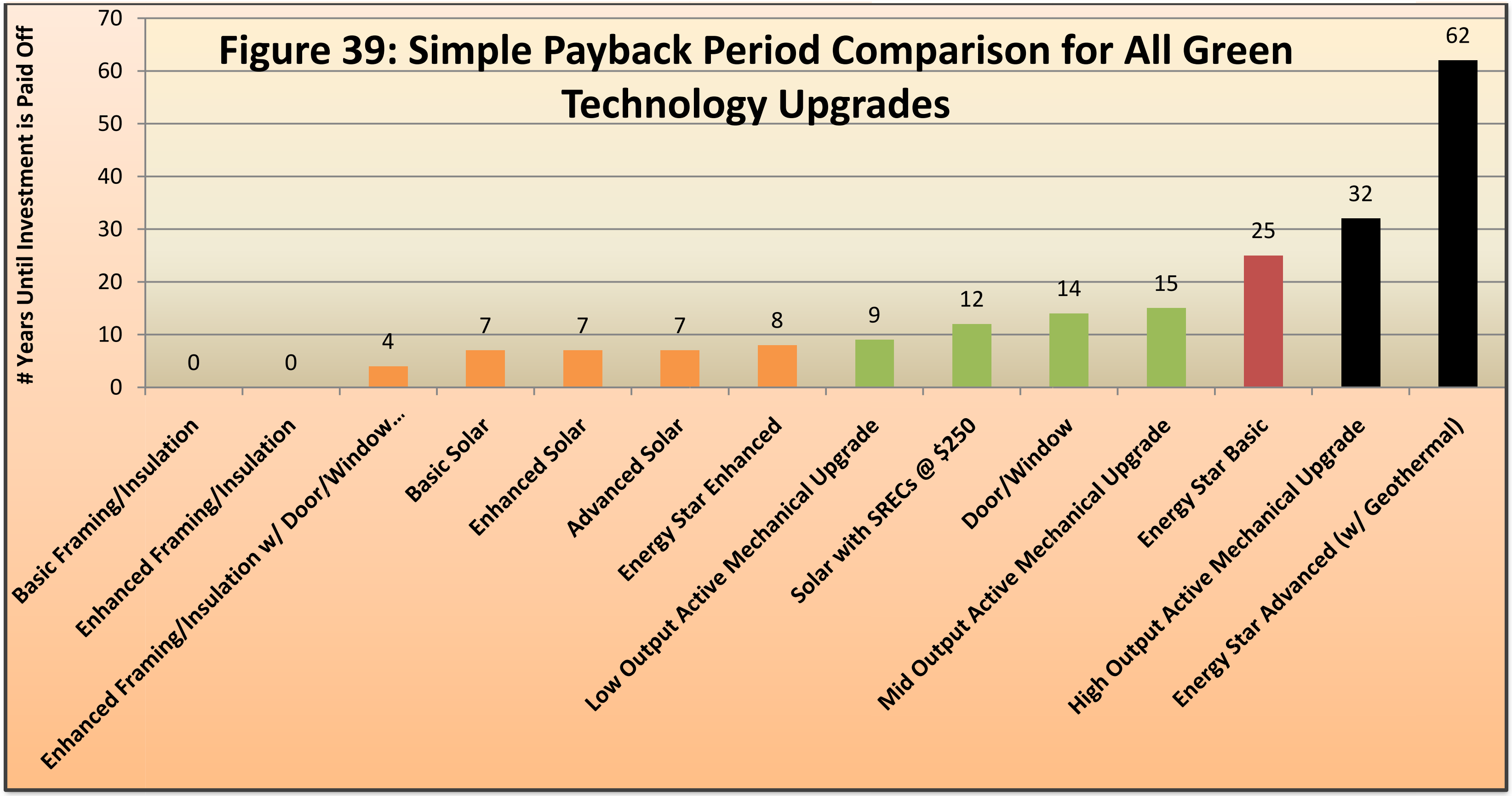
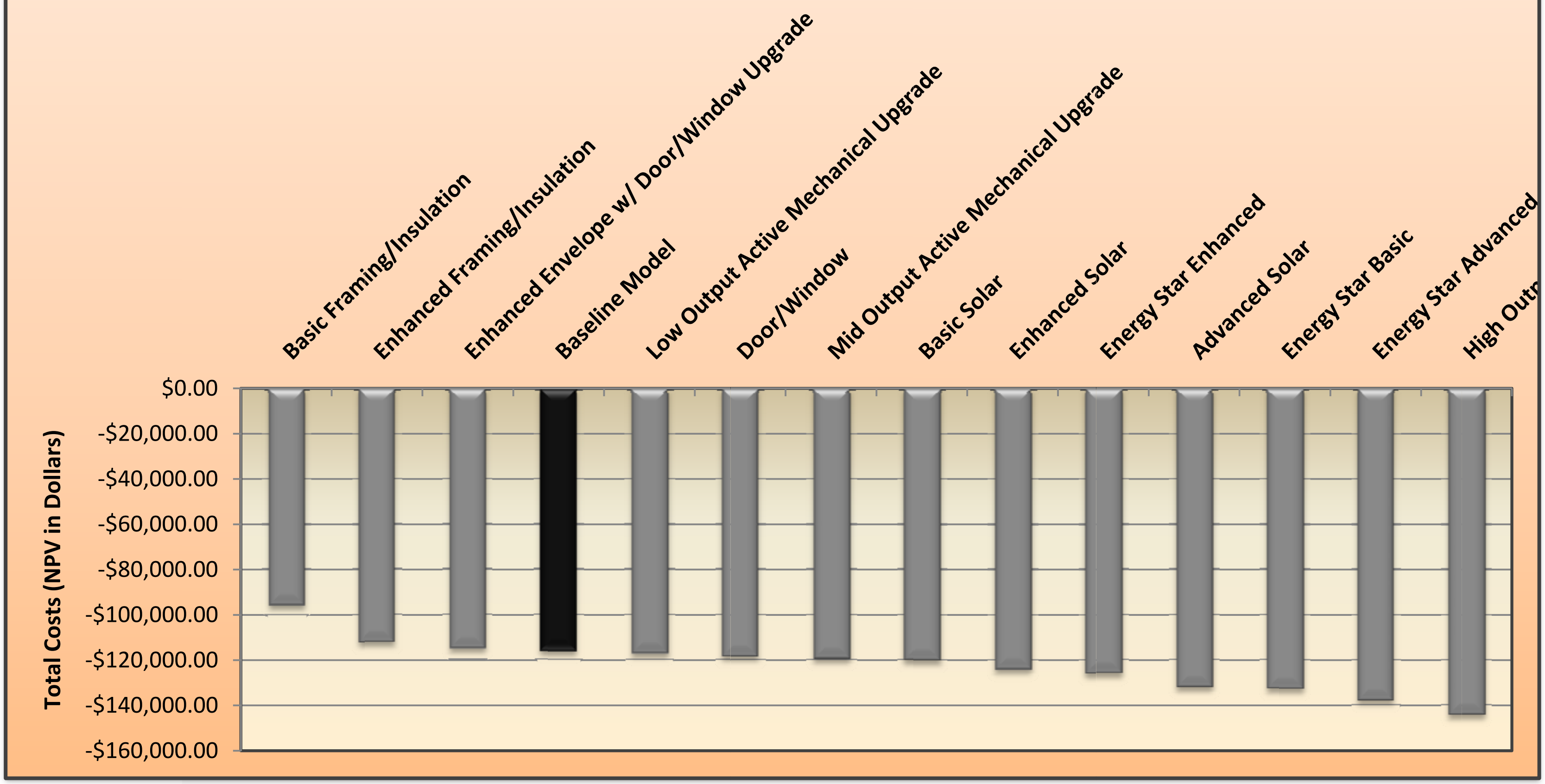


Figure 39: Simple Payback Period Comparison for All Green Technology Upgrades

🟧	Will be paid back within the time of an average home tenure (7 years)
🟩	Will be paid back within the time of a short-term mortgage (15 years)
🟥	Will be paid back within the time of a standard mortgage (30 years)
⬛	Will not be paid back within the time of a standard mortgage

Figure 40: Most Cost-Effective Green Upgrades After 7 Year Time Period



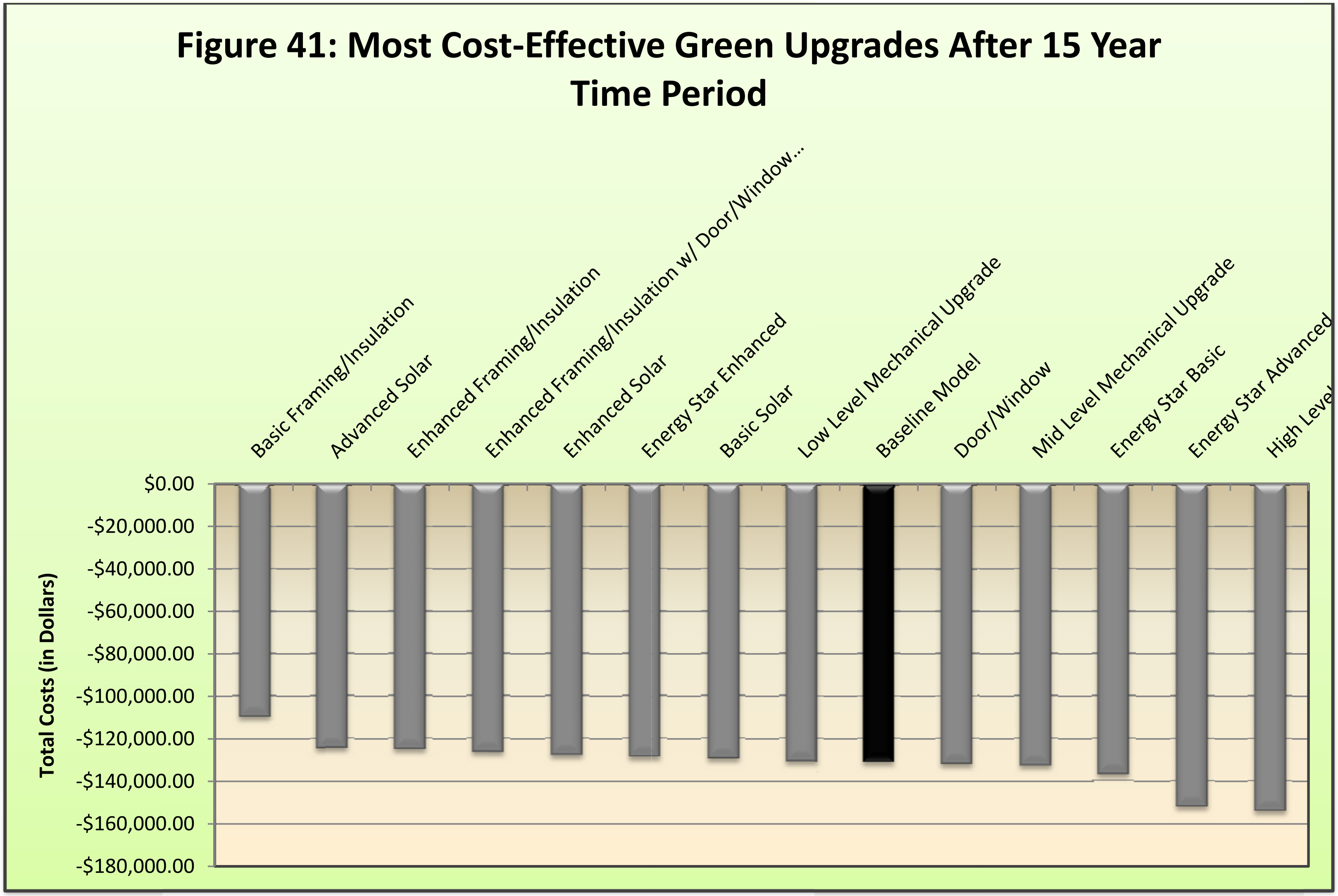


Figure 41: Most Cost-Effective Green Upgrades After 15 Year Time Period

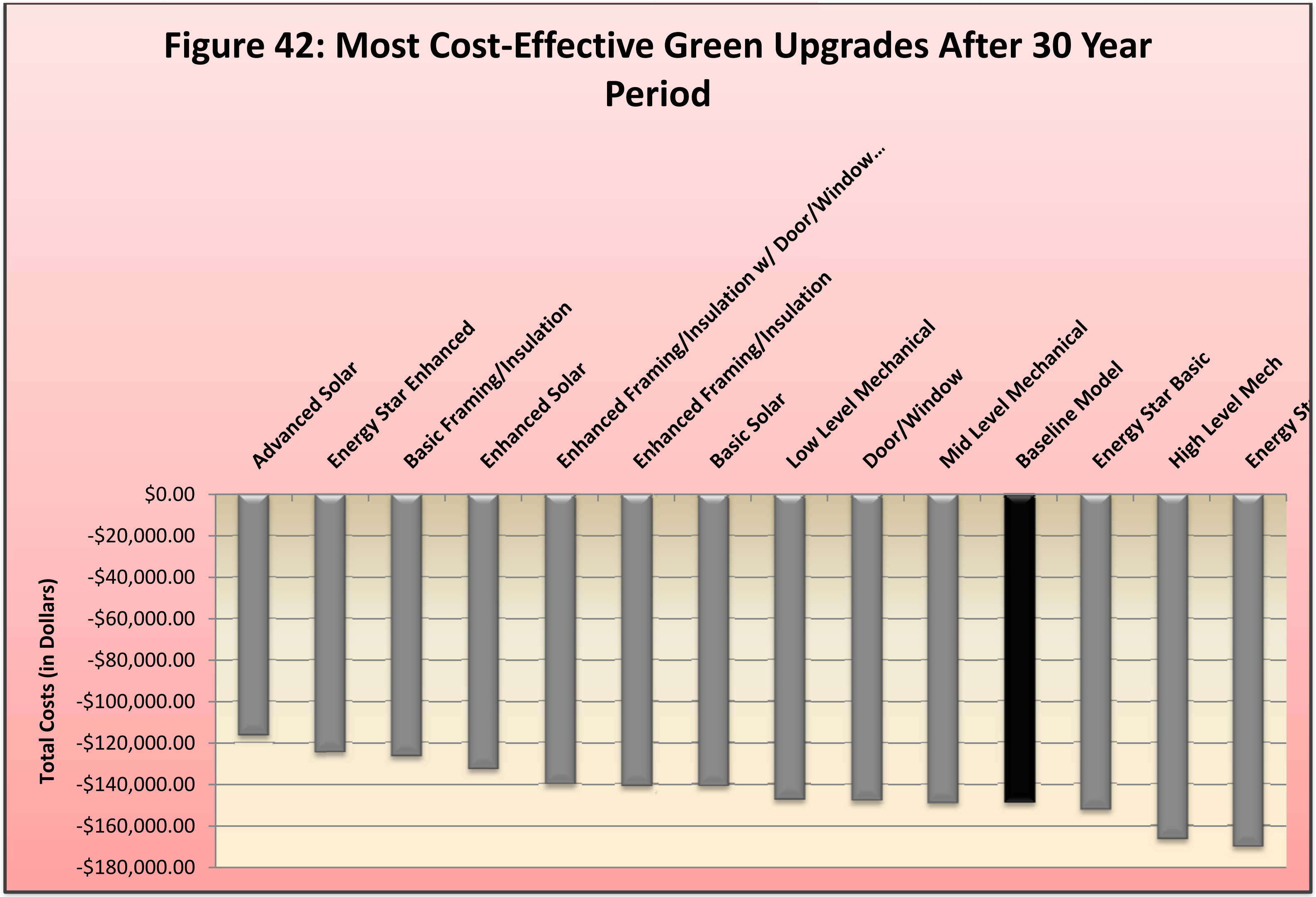


Figure 42: Most Cost-Effective Green Upgrades After 30 Year Period

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7

Glossary

Source: Energy Information Administration, U.S. Department of Energy

End Use: A function for which energy sources or fuels are used in the household. Any specific activity performed requires energy. For the residential sector, the following main energy end-use categories are estimated using RECS data. See Appendix D, "End-Use Estimation Methodology," in Household Energy Consumption and Expenditures 1990 (DOE/EIA-0321(90)).

Space Heating: The use of mechanical equipment to heat all or part of a building to at least 50 degrees Fahrenheit. Includes both the main space-heating and secondary space-heating equipment, but excludes energy used to operate appliances that give off heat as a byproduct.

Air-Conditioning or Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g., air- conditioner or heat pump) or by circulating chilled water through a central cooling or district cooling system.

Appliances: Energy-consuming equipment used in the home during the year for purposes other than condition of air or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black and white television sets, color televisions, water bed heaters, swimming pools, swimming pool heaters, hot tubs, and spas.

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other noncooking applications of hot water. An automatically controlled, thermally insulated vessel designed for heating water and storing heated water at temperatures less than 180 degrees Fahrenheit.

Housing Unit: A house, apartment, group of rooms, or a single room if it is occupied or intended for occupancy, as separate living quarters by a family, individual, or group of one to nine unrelated persons. Prisons and nursing homes are excluded.

Single-Family Detached: A stand-alone structure that provides living space for one household or family. A manufactured house assembled on site is a single-family detached unit, not a mobile home.

8 Appendix 1

8.1 Windows

Conversation with Vendor:

- For Triple Glazed Windows, the highest SHGC based on the technology is 0.23 and the lowest is 0.17.

- Lifetime of windows are full coverage warranty for 50 years than pro-rated after.

8.2 Light Bulbs

CFL & Incandescent: Randolph and Masters 2008

LED: LaMonica 2010 and http://www.nextag.com/a19-led/stores-html

8.3 Structural Overhang

Estimate:

Lowe's

$109 per awning

Americana Building Products 3' Wide by 1'9" Projection White Window Awning

Item#: 139067

Model #: AVU2136W

Design:

http://www.city-data.com/city/New-Brunswick-New-Jersey.html

For New Brunswick, NJ, latitude is 40.49 degrees

Using Randolph and Masters, 2008 page 266 with a pre fabricated projection of 1'-9" (1.75 feet), the calculation for L, D, and H for the REM/Design diagram below is:

$B_{\text{NJune 21}}$=90 – Latitude + Solstice declination = 90 – 40.49 + 23.5 = 73.01

$B_{\text{NDec 21}}$= 90 – Latitude – Solstice declination = 90 – 40.49 – 23.5 = 26.01

Since L= 1.75 feet, we need to solve for D.

D = L tan $B_{\text{NDec 21}}$ = 1.75 tan (26.01) = 0.85 feet

H = 4 feet

8.4 External Doors

http://www.thermatru.com/products/entry/specifications/performance/index.aspx

'ENERGY STAR Qualified Products PDF' where door U Value and SHGC are specified. The column third from the right (with the red arrow) is the type of door used for cost estimation.